ANIMADVERSIONS

On the first part of the

MACHINA COELESTIS

Of the Honourable, Learned, and deservedly Famous

Astronomer

JOHANNES HEVELIUS

CONSUL OF

DANTZICK;

Together with an Explication of some

INSTRUMENTS

MADE BY

ROBERT HOOKE, Professor of Geometry in *Gresham College*, and Fellow of the *Royal Society*.

LONDON,

Printed by *T.R.* for *John Martyn* Printer to the *Royal Society*, at the *Bell* in St. *Pauls* Church-yard. 1674.

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SOME

Tab: IIII.ª

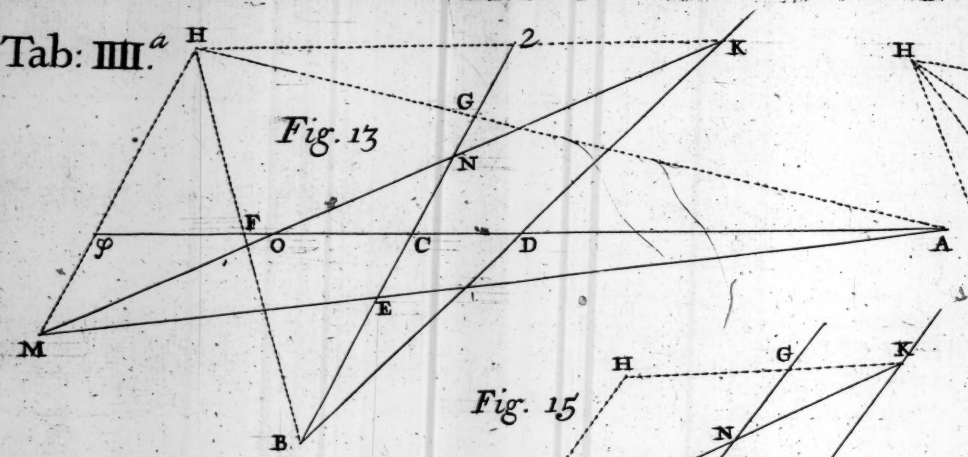
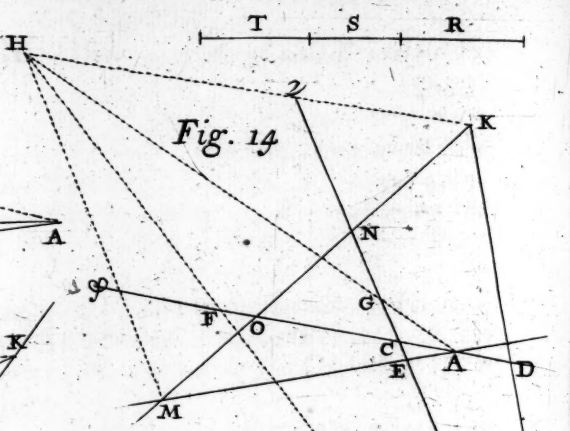


Fig. 13



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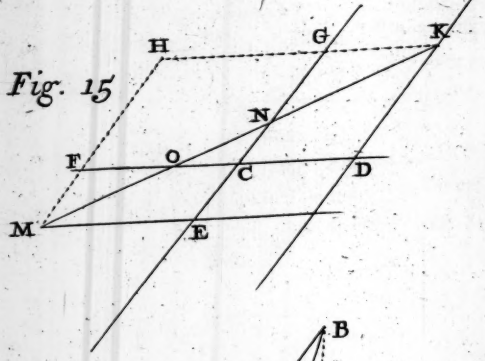

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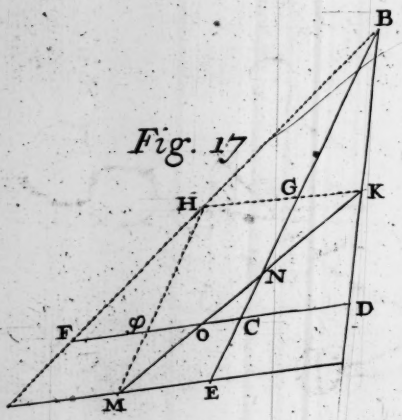

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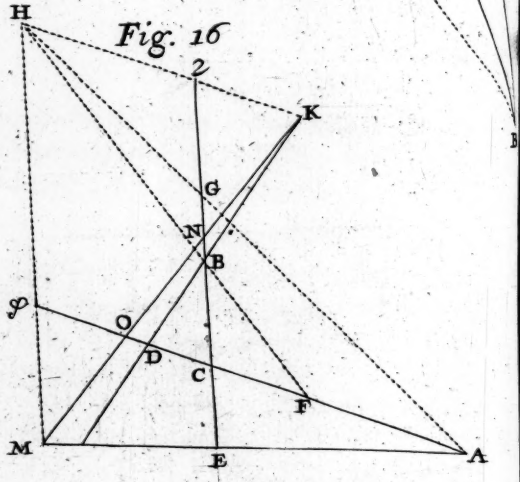

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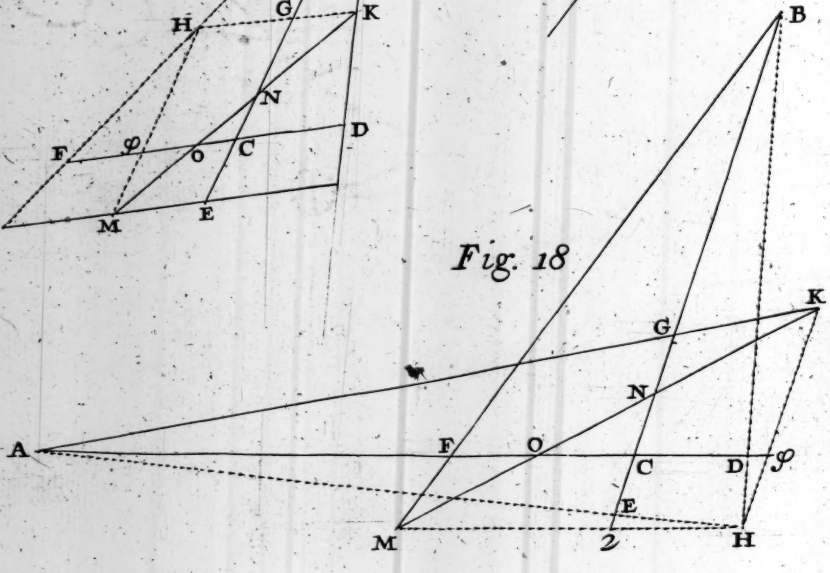

Fig. 18

SOME ANIMADVERSIONS

On the first Part of

HEVELIUS

His *MACHINA COELESTIS*, &c.

HAVING lately perused a Discourse of *Hevelius*, newly published, entituled, *Johannis Hevelii Machina Cœlestis, pars prior Organographiam sive instrumentorum Astronomicorum omnium quibus Autor hactenus sidera rimatus & dimensus est accuratam delineationem & descriptionem, plurimis Iconibus æri inciſis illustratam & exornatam exhibens*, &c. and finding it a Discourse about practical and mechanical Knowledge, and of that kind wherein Geometry seems to be more then ordinarily concerned; I thought it might not be ungrateful to my Auditory, (*nor improper to the Subject of Sr.* JOHN CUTLER's *Lecture, which is partly Mechanical and partly Physical*) to consider a little the Contents thereof: And somewhat the rather too, because having heretofore communicated to him somewhat of this Subject, which I had occasion to read in this place in one of my former *CUTLERIAN* Lectures, I find he hath made some Animadversions and reflections thereupon.

I find then that this excellent Person hath been for the most part exceedingly circumspect, to find out the inconveniences and difficulties that do accrew to the best Observators, even with the best instruments, and has not been less industrious to find out ways to obviate and overcome them; In the doing of which, he seems not to have spared either for labour and vigilancy, or for any cost and charges that might effect his purpose, for which he hath highly merited the esteem of all such as are lovers of that Science: But yet if he had prosecuted that way of improving Astronomical instruments, which I long since communicated to him, I am of opinion he would have done himself and the learned World a much greater piece of service, by saving himself more then $\frac{1}{10}$ of the charge and trouble, and by publishing a Catalogue ten times more accurate. For though I doubt not in the least but that he hath by his own extraordinary diligence, care and cost, corrected several mistakes and errors committed by the assistants of the Noble *Ticho*: yet I am not satisfied that his Instruments are capable of making Observations more accurately then those of *Ticho*, though 'tis possible they may do it with somewhat less trouble and inconvenience. For first, I find that those of *Ticho* were as large as those of *Hevelius*, and consequently were capable of as accurate and minute divisions, and of as long and convenient Sights. Secondly, I find that the Sights made use of by *Hevelius* are the very same, at least not at all materially differing from those of *Ticho*, being only naked Sights, made by a slit and edge, serving only to regulate the direction of the naked eye, but no ways capable of assisting the eye to distinguish more accurately the object. Thirdly, I find that though the way of Division made use of by *Hevelius*, be a very ingenious invention, and that which is Geometrically true and certain, yet if we consider the great difficulty there is in Mechanically performing it, we shall find it not much preferrable, if altogether as good as that of *Ticho*. And 'tis plain enough that *Ticho* himself was not ignorant of it, though his particular reasons why he made no more use of it, we certainly know not: 'Tis very probable, because he thought it not altogether so accurate, as that he did make use of. For somewhat to this purpose he says himself, in the second Book of his Observations of the Comet of

1577.

1577. pag. 461. *Hanc graduum in ſingula minuta*, meaning the Diviſion by Diagonal Lines; *& etiam horum in dena ſcrupula ſecunda ſubdiviſionem in omnibus meis machinis Aſtronomicis uſurpo, eo quod illam multis ab hinc annis exquiſitiſſimam expertus ſum. Licet enim ejus demonſtratio in Rectilineis parallelogrammis propriè conveniat, nihilominus arcualibus etiam in tam exili interſtitio quod à recta linea inſenſibiliter differt, citra omne erroris veſtigium convenienter applicatur.* 'Tis true, *Tycho*'s Objection againſt this way of Diviſion by Diagonals is material, as to a Geometrical accurateneſs, but his Anſwer to it is altogether as material, that though it be not exactly true, yet it doth *inſenſibiliter differre*, and ſo long as the error is not diſcovered by ſenſe, there can be no error committed in obſervation; and indeed the whole matter both one way and the other is inſignificant, and but a vain curioſity to endeavour to divide an inſtrument into ſeconds, or parts ſmaller then a minute, for *I* ſhall by and by ſhew that the eye can hardly diſtinguiſh minutes in the object: But were ſuch niceneſs of Diviſion of any uſe, 'tis eaſily enough to be done to Mathematical truth; for as *I* ſhall anon ſhew, there is a certain diſtance of each of the parallel Circles, which being given, the ſtraight Diagonal Lines will divide the degree, by the interſection with thoſe parallel Circles, into exactly equal parts, which would have better anſwer'd *Tycho*'s Objection, had he known it, which *I* wonder, *I* confeſs, how he could over-ſee, ſince he ſeems to have ſpent many thoughts on the matter; but this only by the By, becauſe *I* ſhall ſpeak more at large of it afterwards. But he proceeds to this other way of Diviſions, which he, as well as *Hevelius*, aſcribes to *Nonnius*, whereas the other that he approves of came firſt from *England*, as it appears by a paſſage in another Book of his, where he diſcourſes ſomewhat of the ſame Subject.

Altera Diviſio ad clariſſimi Mathematici Petri Nonnii *in Libello de crepuſculis propoſitione tertia imitationem per plures quadrantis arcus introrſum deſcriptos, & diverſimodè ſubdiviſos procedit; etſi autem in hac ipſa apprime ingenioſa* Nonnii *inventione aliquid Auctuarii loco expeditius à nobis additum eſt, ita ut exterior arcus in plurimas partiunculas dividatur, neq; is ordo aut numerus arcuum ſeſe introrſum concomitantium quem ille præfinivit*

ſed multo expeditior & perfectior obſervetur; (I am apt to think he knew this very way, and here hints it:) *Tamen quia hæc ſubtilitas cum ad praxin deventum eſt plus habeat laboris quam fructûs, neque id in receſſu præſtet quod prima fronte pollicetur, ut alibi plenius oſtendemus, idcirco apud nos dudum in uſu eſſe deſiit.* From which words, and alſo from what he ſays in his firſt Book of the new Star in 1572. pag. 671. ſpeaking of the compariſon between theſe two ways of Diviſions, to wit, *Sit cujuſcunq; velit ingenioſa certe & apprime utilis eſt diſtributio, quam & ego poſtea arcualibus graduum diviſionibus in quadrantibus ſextantibus & armillis, non inconcinnè aut infrugiferè applicui. Licet enim demonſtratio ejus in ſolis rectilineis ſuperficiebus ad unguem ſe habeat; tamen cum quinorum vel denorum minutorum ſpatium in circumferentiis majuſculis à rectilineo inſenſibiliter differat, hic quoq; ejus uſus ſatis commodus & ratus eſſe poterit, multoq; Nonniana plurimorum arcuum intricata & difficili ſubdiviſione expeditior aptiorq; deprehenditur.* From his Diſcourſe I ſay in theſe two places, and from ſeveral others diſpers'd up and down his Works, which 'twould be too long now to quote, 'tis evident that *Tycho* was not ignorant of this way of Sub-diviſion, ſo much applauded by *Hevelius*, invented by *Petrus Nonnius*, and promoted by *Tycho* himſelf; and yet we ſee he prefer'd that way of Diagonals, firſt made uſe of in *England* by the moſt skilful Mathematician *Richard Cantzler*, before it, rejecting the one and making uſe of the other in all his Inſtruments. But either of them will do well enough if the Diviſions be done with great circumſpection and care, and inſtruments of the ſize of thoſe larger ones both of *Hevelius* and *Tycho*, are capable of Diviſions ten times more accurate then are needful for common Sights, be they never ſo long, without making uſe of either *Tycho*'s or *Hevelius*'s way of Diviſion, the eye being unable to diſtinguiſh a ſmaller Angle. To what purpoſe therefore is it to make the Diviſions ſo fine, or any one part of the inſtrument or obſervation more accurate then another? ſince the power of diſtinguiſhing by the naked eye is that which bounds and limits all the other niceneſs, and whatever part is more curious then that can equalize, is of no ſignificancy. For inſtance, in taking the altitude of a Star, it would be but labour loſt to diſtinguiſh by the Diagonals, or otherwiſe

otherwiſe to Seconds, whilſt in the mean time you are not certain that the Plumb-line is true to a minute, or whilſt you are not able to direct the Ruler, bearing the Sights to a greater certainty then to that of a minute. And the like might be ſaid of the extraordinary curioſity in any two parts, and the failure in any third, that is eſſential to an obſervation; as fruitleſs it is to calculate to ſeconds, when the obſervations are not true to minutes, or to be certain by the Sights and Diviſions to ſeconds, and uncertain in the Plumb-line to minutes.

There is therefore one thing in *Hevelius* his Inſtruments, that though they be never ſo large, never ſo accurately divided, of never ſo choice and convenient materials, and never ſo tractable for uſe, and never ſo skilfully and induſtriouſly uſed, will notwithſtanding make them all equal as to uſe, with one of about two or three foot radius of mettal with *Ticho*'s Sights and Diagonal Diviſions, which is occaſioned by the limited power of diſtinguiſhing by the naked eye.

Something to this purpoſe *I* communicated to *Hevelius* in the year 65. and hoped that *I* might have thereby ſomewhat aſſiſted him in his great and laborious Work, firſt by eaſing the eye, and next by making it capable of diſtinguiſhing more exactly, *I* having hinted to him the way how to reform and obviate that inconvenience by Teleſcopical or Perſpective Sights, as alſo the way of making inſtruments of much leſs bulk, to do ten times more then 'twas poſſible to do with the largeſt inſtruments made the common way. In anſwer to which he returns me this Diſcourſe, in a Letter to the Royal Society, in the year 65.

MODUS ille obſervandi per Teleſcopia adminiculo Sextantis vel Quadrantis, videtur mihi vix adeò tutus, quam vulgaris, ſi pinnacidia rectè ac juſtè ſint affixa. Hæc enim ſunt immobilia; Teleſcopia verò nullâ ratione adeò firmiter affigi poſſunt ut loco haud dimoveantur; etiamſi omni diligentiâ juxta methodum deſcriptum per totum Horizontem experiundo ſint ſemel collocata. Adhuc quàm arduum ſit, eâ ratione verum eorum locum indagare, ſatis ſuperq; expertus ſum; ſic ut vix videam, an alicui

circa

circa restitutionem Fixarum Planetarumq; adminiculo esse possint; in majoribus scilicet illis distantiis capiendis: In minoribus, largior, posse aliquid præstari; seu an Instrumenta, unius Spithamæ radio instructa, elaborari possint multò exactius, quàm optima quævis, vulgares Dioptras habentia, licet 60 pedum radio elaborata, nollem adhuc asseverare. Multa namq; in Theoriâ videntur certissima, quæ in praxi satis longe nonnunquam à vero recedunt. Si quis mihi certas observationes quarundam distantiarum & quidem Fixarum, circa Ecliptican & Æquatorem existentium, illis ipsis Instrumentis, Dioptris Telescopicis instructis habitas exhiberet: (utpote distantiam Lucidæ ♈ à Palilicio; Palilicii à Pollice; Pollucis à Regulo; Reguli à Spicâ ♍; Spicæ ♍ à Boreal. sinist. manus Serpentarii; Boreal. sinist. manus Serpentarii ab Aquilâ; Aquila à Marcab; & Marcab à Lucidâ Arietis) vellem protinus de rei illius certitudine & meum quale quale judicium ferre; sed antequam eas observationes obtineam, judicium suspendo. Interea utiq. fateor; si quis adminiculo minoris cujusdam Instrumenti observationes corporum Cœlestium peragere potest, multo sane illum esse feliciorem, variis de causis, eo, qui per majora id præstare allaborat. Rationes dividendi Instrumenta, diverse quidem mihi probè cognitæ sunt; easq; etiam in usum transtuli; num autem sint eædem quas Clarissimus Dominus Hookius *novit, ac invenit, me prorsus latet: Si illi non adversum est, rogo, ut præcipuas communicet, ego ut meas intelligat rursus studebo.*

Since which time *I* have not sent any other description of instruments, save that of the manner of making and using a Tube for a 60 foot Glass, which *I* am much pleas'd to find he makes use of, and should gladly have communicated any thing further, if *I* had not found they were esteemed insignificant. *It* did much trouble me, *I* confess, that *I* could not prevail with him to make use of Telescopical Sights at least, since with less trouble he would have afforded the World Observations, and a Catalogue of the Stars, ten times more exact. And *I* am the more sorry to find that he hath proceeded to finish his *Machina Cœlestis*, by instruments not more accurate then those of *Tycho*, and that he still remains in the same opinion of Telescopical Sights, and other improvements of instruments. For pag. 293. of this first Part of his *Machina Cœlestis*, speaking concerning

Sights,

Sights, he ſays, Poſſibly ſome may wonder that *I* do not make uſe of Teleſcopical Sights, ſince they are by ſome accounted better and more accurate, inſomuch that there is one in the World hath proceeded ſo far, as to ſuppoſe Teleſcopical Sights to be ten, twenty, thirty, nay forty times more accurate then the common Sights; and that 'tis poſſible to make an inſtrument of a Span Radius to do more with Teleſcopical Sights, then an inſtrument of 60 foot with the common Sights. 'Twould be a thing of much moment could it be done, and not to be valued by money, but many things do ſeem true in the Theory, which do not anſwer upon Experience. You may perceive by comparing this ſlender Refutation with his Letter before, who he means by the Aſſertor of Teleſcopical Sights. But *I* am troubled he ſhould think them ſo ſlight as not to deſerve one tryal in ſeven years time, eſpecially ſince by explaining the manner of making uſe of them much in the ſame ſenſe with that which *I* ſent him, he ſeems to have underſtood enough of the way to have made uſe of it if he would. As to his Objection, That the Glaſſes are apt to be broke, and the Pins or Threads are apt to be bent and broke, there is not the leaſt colour for it, for they cannot without much labour and deſign be broken or put out of order, but if they were, it might as well be ſaid, that the Plumb-line of any of his inſtruments may be broken, or his Sights bended, and the like, and therefore thoſe inſtruments were not to be uſed. But theſe Objections *I* ſhall not urge againſt his inſtruments, nor a great many other *I* could produce of leſſer moment, but only this one which is very fundamental, and cannot any ways be helped but by the help of Glaſſes, and that is, 'Tis impoſſible with Sights made after *Ticho*'s or *Hevelius* his way, to diſtinguiſh any diſtance in the Heavens leſs then half a minute, or thirty Seconds, and hardly one of a hundred can diſtinguiſh a minute.

And this being proved, what will become of all the machinations and contrivances for greater inſtruments, to ſhew the Diviſions of ſingle or double Seconds? May not ſingle minutes, nay half minutes, by the help of Diagonal Diviſions, be ſufficiently diſtinguiſhed in an inſtrument of three foot Radius? What need is there then of all the other cumber? Certainly any one that will but try with the one and the other inſtrument,

will

will find himself able to do as much with an instrument of three foot, as with one of threescore, since the eye cannot distinguish a less Angle, at least none that *I* have yet met with hitherto. Who is there that by his bare eye can distinguish any of the Telescopical spots in the Moon, though some of them are above a minute in Diameter? As for instance, Who can see Mount *Sinai*, so call'd by *Hevelius*, which is a bright spot in a dark field, and consequently must appear near two minutes in Diameter to the naked eye? Or who can see the *Palus Mæotis*, or the *Lacus niger*, which are two dark spots in light fields, and each more then a minute in Diameter? Now if the eye cannot distinguish a smaller object then appears within the angle of half a minute, 'tis not possible to make any observation more accurate, be the instrument never so large.

Now that any one may presently satisfie himself of the truth of what *I* assert, concerning the limited power of the naked eye, as to the distinguishing of Angles; Let him take a sheet of white Paper, and thereon draw two parallel Lines, as O O, and P P, in the 28th. Figure, at four or five inches distance, then draw as many other small lines between them at right angles to them, and parallel one with another, as he thinks convenient, as a a, b b, c c, d d, e e, f f, g g, h h, i i, *&c.* and let them be drawn distant from each other an inch, then let him alternately blacken or shadow the spaces between them, as between a a and b b, between c c and d d, between e e and f f, between g g and h h, between i i and k k, between l l and m m, *&c.* leaving the other alternately white, then let him expose this Paper against a Wall open to the light, and if it may be so that the Sun may shine on it, and removing himself backwards for the space of 287½ feet, let him try whether he can distinguish it, and number the dark and light spaces, and if his eyes be so good that he can, then let him still go further backwards and backwards from the same, till he finds his eyes unable any longer to distinguish those Diwisions, there let him make a stand, and measure the distance from his eye to the aforesaid Paper, and try by calculation under what Angle each of those black and white spaces appears to his eye, for by that means it will be manifest how small an Angle his eye is capable of distinguishing, and beyond which it cannot reach: Which being

being once known, he hath a Standard, by which he is able to limit the bigneſs and exactneſs of his Inſtruments, if he make uſe of common Sights, beyond which all magnitude and curioſity is not only uſeleſs, but of much detriment upon many accounts.

This is that Conſideration which I could wiſh had occur'd both to *Ticho Brahe* and to *Hevelius*, eſpecially to the latter, who hath ſo earneſtly endeavour'd to out-do the former, and for the accompliſhment thereof, ſeems to have ſpared no charge, labour, or endeavour he was able to expend. I hope at leaſt that this publick notice will for the future engage all ſuch as ſhall attempt this Work, to be as ſollicitous about aſſiſting the Eye in the diſcovery of the parts of the Object, as of diſtinguiſhing the Diviſions of the Inſtrument, for the doing of the one without being able to reach the other, will avail nothing.

Thoſe therefore that deſire or need Inſtruments to make Obſervations to Seconds, muſt take another courſe then any that I know yet deſcribed. 'Tis true indeed, That Altitudes of the Sun may be taken, with the Sights commonly uſed for that purpoſe, to what accurateneſs is deſired, if the Inſtrument be large enough, becauſe the Image of the Sun being tranſmitted by the upper Sight through a ſmall round hole, is repreſented within a Circle upon the lower Sight, and by means of the eyes approaching near that Sight, 'tis poſſible by Inſtruments large enough, to arrive at the accurateneſs of a Second, in Obſervations made of that kind. And ſomewhat of this may be done alſo by the Moon, when very bright and clear, but in all the other celeſtial Bodies it has never yet been done.

But then if we compare even this way with that of Teleſcopes, *cæteris paribus*, we ſhall find it much ſhort, both as to clearneſs and diſtinctneſs, and therefore even here alſo Teleſcopical Sights are to be preferred, as I ſhall ſufficiently manifeſt hereafter more at large, when I come to deſcribe my own Inſtruments for this purpoſe; for I doubt not but to make it ſufficiently plain, That by the help of an Inſtrument I have contrived, of three foot Radius, I will be able to make all Obſervations whatſoever, ten times more accurate, excepting thoſe of the Sun, then any one can make with the largeſt Inſtrument,

ſtrument, deſcribed either by *Tycho* or *Hevelius*, and to manage the ſame with a quarter the trouble, clutter, and *apparatus* neceſſary to either of theirs, and to make the Diviſions as accurate and ſenſible as can be deſired.

For the doing of which, I will ſhew, Firſt, How to make the Plain of the Inſtrument, that it ſhall not be ſubject to bending or warping, and yet be ſo light as to be eaſily manageable. Secondly, How to make the Diviſions on that Inſtrument, ſo as to diſtinguiſh certainly and exactly to Seconds, without any trouble, or wearying the ſight. Thirdly, I will ſhew how to make the Sights of that Inſtrument, ſo as to diſtinguiſh the parts of the Object to Seconds, if need be, even by thoſe who cannot diſtinguiſh to Minutes with common Sights, certainly, and without fallacy or error. Fourthly, How to make the Sights, ſo as to ſee two Objects, though never ſo far diſtant, with one glance of the eye. And Fifthly, I will ſhew how to adjuſt the Perpendicular, ſo as to ſet it exactly upright and plain to a Second, ſo that if it meets with a diligent, accurate, and experienced Obſervator, it will ſerve to make as curious Obſervations as are hitherto deſirable. Sixthly, I will ſhew a way how to fix this Inſtrument, either for taking Altitudes or Azimiths, ſo as to be manageable with the leaſt trouble imaginable, for Obſervations of that kind, and to be always ſteady and fixt in any Perpendicular poſture, to whatever Azimith it be apply'd. Seventhly, I will explain an exact way for fixing the Inſtrument, ſo as to take the Diſtances of any two Stars, or celeſtial Object, and ſeveral other contrivances of the like nature. But of each of theſe hereafter, after I have examin'd over the ſeveral particulars mention'd by *Hevelius*, in his Deſcriptions of the Inſtruments and Contrivances made uſe of by himſelf.

To paſs by then his long Preface, and the Diſcourſe of Inſtruments in general, which he hath premiſed in the firſt Chapter; I ſhall proceed to an examination of thoſe Inſtruments of his own, which he doth more fully and particularly deſcribe.

The firſt of which kind I find to be a Quadrant of Braſs, which he deſcribes in the ſecond Chapter, and begins with that firſt, as being an Inſtrument which he leaſt eſteem'd, and

which

which at length he made no uſe of, though for many Reaſons I think of a quantity big enough, to be as good, nay better, then any he made uſe of. But of that anon.

This Braſs Quadrant was of three foot Radius, and ſo well fitted with croſs Bars, and ſtrengthned, that it was not ſubject to warp or bend; it had alſo a convenient Pedeſtal, and was made eaſie to be removed from place to place; it was ſuſpended by a Cylinder placed on the back-ſide, in the Center of Gravity of the Quadrant, and could by this means more eaſily be moved to and fro to take any Altitude, then that way of *Tycho*'s, who fixt his Cylinder at the upper corner: But it hath this of inconvenience that *Tycho*'s hath not, namely, That the Plumb-Line or Perpendicular will be longer before it ſettle, and the Inſtrument ſomewhat more apt to warp. The Sights of it are the ſame with that of *Tycho*, and indeed the beſt of Common Sights, now commonly every where made uſe of in Inſtruments of that bigneſs, but far inferior to thoſe which are made of Glaſſes, as I ſhall afterwards prove.

The way of Sights which he deſcribes, *pag.* 98. for taking the Altitude of the Sun, is very good, but yet far inferior to one fitted with the Object-Glaſs of a Teleſcope, though he had omitted the Tube, for he might thereby have enlarged the hole of the upper Sight to what bigneſs he pleaſed, and conſequently have made the image of the Sun as bright as it ſhould be thought convenient, and that without any manner of Penumbra, if the lower Sight were placed at the due diſtance of the Focus of that Object-Glaſs. And therefore I do wonder at his carefulneſs to inform his Reader aright, for fear he ſhould underſtand a Teleſcope by the Tube he made uſe of, to keep off the adventitious light from the lower Sight, ſaying, *pag.* 99 *Per Tubum autem mi Lector non intelligo Teleſcopium aliquod lentibus inſtructum, ſed plane nudam ex charta conſtructum Tubulum*, as if he had ſome dread of making uſe of Glaſſes in any of his Sights. Whether it were, that he ſuppoſed Glaſſes to have ſome hidden, un-intelligible, and myſterious way of repreſenting the Object, or whether from their fragility, or from their uncertain refraction, or from a ſuppoſed impoſſibility of fixing them to the Sights, or whether from ſome other myſterious cauſe, which *I* am not able to think of or imagine, *I* cannot

tell. Sure I am, that none of these I have named, are any thing at all considerable Objections against their use, and I have been so fully satisfied of the exceeding great use, nay absolute necessity of them in curious and exact Observations, that I do assure him there is not, nor can be any considerable Objection against them, which cannot easily be answer'd, nor any inconvenience, which cannot with ease be obviated and rectified; of which I shall say more hereafter.

The Divisions of it were made wholly by himself, with extraordinary labour and curiosity, insomuch that he says, he could not only distinguish each minute of a Degree, but almost every quarter of a minute, sufficiently accurate for his Common Sights, if he could have only distinguished every half minute, and indeed much more then most mens eyes are able to reach. He seems to have been at infinite trouble and pains, to perform the Divisions made by the help of Diagonals, cutting parallel Circles, a way made use of by *Tycho*, and now so commonly known, that I think I need not spend time in the Explication thereof; only I must take notice, That whereas he supposes these Circles to be equally distant, he ought to have placed their Distances according to the Proportions of the differences of the Secants of some ten minutes, next successively following one another in some Degree of the Quadrant, which is easie to determine, from the Distance of the two extream or bounding Circles; of which more hereafter.

Now though the Circles ought not according to the strict Rules of Geometry, to be equally distant from each other, as *Hevelius* seems to suppose, yet I confess, unless the space wherein these Circles lye be very large, and the parts of a Degree that are to be distinguisht, very small, there is no necessity of so curiously distinguishing those unequal Distances, but they may serve well enough for use, if they be taken equal, as *Hevelius* supposes, and indeed much more accurate, then 'tis possible to distinguish the Object by the bare eye; and therefore I shall not need to insist upon the further Explication thereof, especially because when I come to shew a more accurate way of Sights, I shall also shew a much more accurate way of Division, then either of those two of *Tycho Brahe*, or this set down by *Hevelius*, which is much the same with one of those

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which was 100 years since made use of by *Tycho*, and described, and is by him attributed to an English Mathematicians.

But because this industrious and careful Person put himself to the trouble, of making and examining the Divisions himself, I could heartily have wisht he had thought upon some such way as this, which I here describe, and call a Compendium of Diagonal Divisions, it being a way, whereby as $\frac{9}{10}$ of the trouble is saved, in performing the manual operation thereof, so I judg it to be much more certain, exact and plain, then the other way of Diagonals. My Reason for the first is plain, The Division of one Degree serving for the whole ninety: And my Reasons for the second are, First, Because it is much plainer to be distinguished, then by the help of the edge of a Ruler, lying over the Diagonals, one being able to see but one part of the Diagonal. And Secondly, I think it much better then a small fiducial Thread, which is very apt to be bended and broken, if it lyes close to the Superficies of the Diagonal, and if it lyes at a distance, a skew glance of the eye will much alter the seeming intersection of the Diagonals, which in this way are both prevented. The way then in short is nothing but this; Take a thin piece of clear Looking-glass Plate, well smoothed and polished on both sides, and large enough one way to cover the whole breadth of the Rim of the Quadrant, on which the Diagonals were to be made, and the other way to cover two or three Degrees, (this I do the bigger, that the sides of the Arm may not shadow or darken the Divisions and numbrings.) Suppose a a a a in the 29th. Figure, Plate 2. to represent such a Plate, upon this Plate describe with great care a Degree of the Quadrant you would have divided, and compleat it with all its parallel Circles and Diagonals, as you would have done any one Degree upon the Quadrant, and if the Rim of the Quadrant be very broad in proportion to its Radius, you may by the Table of natural Secants or Tangents, set the parallels at their due Distances, but if the Rim be narrow, 'twill be sufficiently accurate to make their Distances equal. These Divisions must be done with Compasses, pointed with small Diamant Points, in the manner of those wherewith Glasiers cut their Glass. The Glass being thus divided and lined, number the

Diagonals,

Diagonals, and place it in the Frame of the Ruler, with the lined ſide next the Quadrant, ſo that moving it to and fro, the ſide of the Glaſs may immediately touch the Braſs Rim of the Quadrant. This Braſs Rim muſt be divided into 90 equal parts or Degrees, and at each Diviſion ſtraight Lines drawn from the Circumference towards the Center, the whole breadth of the Limb, (at leaſt as much as is made uſe of for the Glaſs-Plate, for the breadth of the Diagonals) the Frame to carry this Plate is a convenient Cavity, left in the moveable Arm of the Quadrant, the whole manner of which will be better underſtood by the Delineation thereof, to which I ſhall therefore refer the Reader. The Diſtances of the parallel Circles if unequal, may be eaſily ſet down true, according to the numbers of natural Tangents or Secants, with a pair of Compaſſes, contrived like Beam-Compaſſes, but having its Points to be ſet at any diſtance, deſired by the help of a Screw, moving upon one ſide of the Beam, which I may have occaſion to deſcribe elſewhere more properly, and therefore will here omit it.

Next, If this way had not pleaſed, I could have wiſhed he had known this following, which is altogether as eaſie, and as Geometrically true, which I have contrived, and have made ſmall Inſtruments thereby to ſhew very minute Diviſions, very eaſily and very plainly. I ſtrike then upon the Limb of the Quadrant I would divide, being firſt made exceeding ſmooth and plain, a Circu e very fine, and as lightly as poſſibly I can, ſo it be but diſcernable, and by the help of a very large Quadrantal Dividing Plate of ten foot Radius, I divide the ſaid Quadrant in the faint Circle above-mention'd, into 90 parts or Degrees, then by a peculiar contrivance of a very curious Point that ſtrikes with a Spring, which I deſcribe in another Diſcourſe, the ſaid Degrees are marked upon the Plate by curious, ſmall, round and deep holes, theſe are by another Line without it, which is divided and figured the Common way, diſtinguiſhed and numbred by Figures, according to the Common manner. Then for the ſub-Diviſions, I make a ſmall Hold-faſt by a Screw, which is fixed on to the moveable Arm of the Quadrant, this ſerves to hold the end of a Diagonal Hair, the other end of which is ſtrain'd over the Supplementary Degree, till it lyeth directly over ſome prickt-Hole of the curi-

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ous Diviſions, on the Limb of the Quadrant, this gives me the ſub-Diviſions of the Quadrant, to what accurateneſs I deſire. The Supplementary Degree is a Degree of a very large Circle, put on upon a ſmall Rule, fixed on to the ſide of the moveable Arm, whoſe Magnitude and Diſtance is found by this Proportion, as the Diſtance between the end of the ſmall Hold-faſt and the pointed Circle, is to the Radius of that Circle, ſo make the Diſtance between the ſaid End and the Supplementary Circle to the Radius of that Circle. This will be more plain by a Scheme.

Let a a a in the 30th. Figure repreſent a Quadrant, b b b a very fine Circle, ſtruck on the Limb of the Quadrant, from the Center l, which by a large Quadrant of 10 foot Radius, I divide into Degrees, and by a ſpringing Point ſtrike ſo many ſmall Points, and number them to 90. beginning at m, and numbring towards i. Let d d repreſent the moveable Arm, c c the hold-faſt, fixed upon the ſide of that Arm, which by a ſmall Screw pincheth and holds faſt a very fine Hair at k, ee the ſmall Ruler fixed at right Angles, with the Line l k f, in this Line (through the Points l and k) I take a Point, as f, and through f I ſtrike a part of a Circle f g, whoſe Center is ſomewhere in the Line f k l produced, which I find by reſolving this Proportion, as k i is to l i, ſo will k f be to the Radius of the Supplementary Circle f g, which will fall ſomewhere in f k l produced, towards l, then take a Degree of that Circle, which will extend from f to g, and divide it into as minute Diviſions as are neceſſary, and number them from f to g. Now to find what Angle the Sight d d maketh with the Sight m m, I ſtrain the Hair h k, till I find it lye over the next Diviſion Point towards the right hand, and obſerve in the Ruler e e, what part of a Degree is there marked, and on the Circle b b b, what Degree is marked, the ſum of both which gives me the true Meaſure of the Angle d d l m. But this only by the By, and I will not now further enlarge on the Explication thereof, deſigning it for another Diſcourſe, where I ſhall deſcribe various, Mechanical and Practical ways, of accurately dividing Lines, into any aſſignable number of equal or proportional parts.

To proceed then where I left off, to the examination of the

the Instruments of *Hevelius*, I find that together with the Brass Quadrant I was speaking of, he describes two Contrivances about it; The first is, How to set it presently to an upright, without the trouble of turning the Screws in the Pedestal, which is plain enough, and so much the better; but it hath this of inconvenience, that it must be altered for every Azimith, which is a very great one, and which by another way altogether as easie and plain, may be avoided; of which more hereafter.

Another Contrivance about this *I*nstrument, is a small Screw, for moving it and keeping it steady in any posture in the same Azimith, which is convenient enough, but will not perform what he afterwards supposes it capable of, as *I* shall afterwards shew.

The second *I*nstrument, which in the third Chapter, *pag.* 102, 103, *&c.* 108. he describes, is a Sextant of Brass, of three foot Radius, carefully made, and divided with the same care and after the same way as the former. The Sights also are much the same, only whereas in the Quadrant he makes use of a Plate, with parallel edges for the Sight that is at the center, and furthest from the eye; in this he makes use of a Cylinder, which way also *Ticho* made use of 100 years ago, and hath been ever since made use of. The other Sights next the eye are the same with the former: There is nothing singular in the Pedestal, nor in the Ball and Socket, only 'tis somewhat bigger then ordinary. His way of moving and fixing the Rule of it is convenient enough, and the same with his *I*nstruuent for moving and fixing his Quadrant, but 'tis not capable of performing what he promiseth for it.

The third *I*nstrument, which in the fourth Chapter he describes, is a Sextant of *I*ron, of four foot Radius, to be managed only by one Observator, by putting the Center next the eye. The whole *I*nstrument is little differing from the former, save only that the Cylinder at the Center which is here next the eye, is cover'd with another hollow Cylinder, which is voluble and convertible about the former, and carries two small Slits for the Sights, which performeth the same as the other Sights, but nothing more, and as the Author himself affirms, is not so accurate for use as the other Sextant, where there

there are two Obſervators, and therefore was ſeldom made uſe of by him. But I ſhall anon ſhew a way by which one Obſervator alone ſhall be able to take any Diſtance to a Semicircle with much more accurateneſs and conveniency then any two Obſervators can; and therefore will be an Inſtrument of the beſt uſe for Aſtronomical and Nautical affairs, for the perfecting both which I deſign it.

The fourth Inſtrument, which in the fifth Chapter, from *pag.* 114, *&c.* to 123. he deſcribes, is a Quadrant of ſix foot Radius, whoſe Frame was all made of dry Oak, but the Limb, Sights, Sockets, *&c.* were made of Braſs, divided ſo as to ſee every quarter of a Minute diſtinctly, the Sights the ſame as in the firſt Quadrant, and the way of ſuſpending it not much differing, ſave only, whereas in the former the Pedeſtal was moveable, in this it is fixt, which is much better. And the Inſtrument is kept in an *Æquilibrium*, by the help of counterpoiſes hung at the end of a ſtring, and caſt over a Pully, as is more viſible by his Deſcription. But this (as all other wooden Inſtruments do) he found to ſhrink and warp, and conſequently to loſe its exactneſs, and therefore he made little or no uſe thereof, but laid it aſide, and made himſelf better of Braſs.

The fifth Inſtrument deſcribed in the ſixth Chapter, from *pag.* 123. to 132. is a Sextant of Wood of ſix foot Radius, made in all particulars like the former Sextant of Braſs of three foot; nor has it any other contrivance about it conſiderable, ſave only a reſt made to ſlip up and down for the Obſervators to reſt their Elbows upon. But this Inſtrument alſo he found to be vitiated by the ſhrinking and warping of the Wood, and therefore he laid that by alſo, and ſeldom made uſe of it.

The ſixth Inſtrument is a large Octant of Wood of eight foot Radius; this is made exactly according to the Form of *Ticho*'s Octant, and ſerves for taking any Diſtance not exceeding 45 degrees. The Sights near the eye are made exactly as the former, but moveable, ſo as to ſlip upon the Limbs of the Octant; the Diviſions of it are performed by Diagonals as before, and gives a greater niceneſs of Diviſion then the Eye is capable of diſtinguiſhing in the Object, and therefore of little uſe.

And thus far the Author proceeded in *Ticho*'s way. But finding theſe Inſtruments which were made for the moſt

part of Wood to be ſubject to faileur, he aſpired to get better Inſtruments made all of Braſs or Iron, and wholly laid aſide the reſt as altogether uſeleſs. And I cannot but very much approve of his Judgment in ſo doing, for certainly *cæteris paribus* Inſtruments, well made of Braſs or Iron, are much to be preferred before the beſt of Wood. But yet neither are all manner of Wooden Inſtruments to be rejected; nor are all ſorts of Metalline Inſtruments free from error, though 'tis confeſſed, if they be made and uſed with skill, they ſuffer not any conſiderable or ſenſible variation. Firſt, I ſay, Wooden Inſtruments may be ſo contriv'd as very near to equalize thoſe of Metal, the Joynts and Plates for Diviſions only being made of Metal, they being very eaſie to be rectified before, and examined after every time of uſing. Such a one was contrived by Sir *Chriſtopher Wren*, being two ſquare Wooden Tubes or Teleſcopes, joyn'd together at the end next the Object by a Joynt of Braſs, and the Angle made by the opening of them, meaſured by a ſtraight Rule equal to half the Radius, divided by Diagonals into 5000 equal parts, which will by the help of a Table of natural Signs or Subtenſes, ſhew the parts in Degrees, Minutes, and Seconds, of which I think I acquainted *Hevelius* ſome years ſince. Next Braſs and Metalline Inſtruments, if they be not very carefully fortified againſt it, are more apt to bend then even thoſe of Wood. And the beſt way I have found to ſecure them true and plain in all poſtures, is to lay them on a Table or Frame of Wood, well fortified underneath againſt bending, and by the help of ſmall Screws in ſeveral parts of the Inſtrument to adjuſt it upon that Frame; the whole Table and Quadrant being ſo counterpois'd, as to be eaſily moveable and fixt in any poſture. But *Hevelius* is pleas'd, as I ſaid before, wholly to lay aſide all manner of Wooden Inſtruments as uſeleſs, and to indeavour the obtaining of Inſtruments of Braſs or Iron. *Nam* (ſayes he pag. 136.) *cùm longâ experientiâ probe tandem didicerim, multo ſecurius eſſe ex ſolido p orſus metallo obtinere Inſtrumenta, tum quo majora & ampliora eo eſſe accuratiora & abſolutiora, adhæc prioribus admodum Tichonicum conſtructis plurima deeſſe quibus ditari merito deberent, & quod iiſdem de cauſis omnino neceſſum ſit, ut parte corrigerentur & meliorentur, tam quà eorum materiam fructuram commotionem facilitandam diviſionem quam*

alia

alia diversa subsidia & adminicula, quo sic aptius, exquisitius, promptius, minorique labore, &c. ac temporis dispendio possent Astris exponi observationesque peragi. Idcirco omnem curam atque operam pro tenui ingenii mei facultatúmque mearum modulo à Deo concesso (reliqua sublimioribus ingeniis atque ampliori fortunâ Viris, sive posteritati nostræ relinquens) adhibui: quo minora, tam lignea universa ab Astris planè removerem, atque in ejus locum ex puro solidóque metallo, organa mihi compararem: & quidem ejusmodi, quæ insigni amplitudine essent conspicua, simul commoditate regendi, simul aliquanto accuratioribus adhuc divisionibus, ad paulò subtiliores observationes obtinendas gauderent. His Reasoning indeed is very good, that since he had from much and long experience learn'd, that Instruments of Wood after *Tycho*'s manner, were not to be trusted to by reason of their warping and shrinking, and consequently that Instruments of solid Metall were much to be preferred before them, and also that the larger the Instruments were, the more exactly they could be made and divided, and that the more easie they were to be moved, and the more steddy and sure they were to be fixt in any position, the more convenient they were for use, he had therefore rejected all those Instruments which he had made after *Tycho*'s way; and had indeavoured to procure for his own use such as were compleat, both for their matter and form, having caused them to be made of Mettal that which could not be subject to the inconvenience of warping, swelling, or shrinking, with the variety of Weather, or length of Time: And likewise of such a bigness as was capable of receiving more nice and curious Divisions; and in the dividing them had found such contrivances, and used such diligence, that they were more then ordinarily true and exact. As far as he has gone on with these Designs, he seems to have been even profuse in his expences, and exceeding bountiful of his own care, labour, and diligence; but I could have wish'd heartily that it had been some other way imploy'd. Those Instruments which he chiefly laboured to perfect, he professes to be Quadrants, Sectants, and Octants, after *Tycho*'s manner, rejecting all other Instruments of whatsoever Figures, whether *Radii*, *Astrolabs*, *Zodiacal* or *Æquinoctial Rings*, *Parallactical Instruments* or *Hoops*, as more troublesome, and less accurate. But whether he hath in this his

choice been rightly adviſed, I ſhall hereafter have more occa ſion to examine when I come to deſcribe an Apparatus of In-ſtruments neceſſary for ſuch a one as deſigns to promote and perfect the knowledge of the Cœleſtial Bodies and their motions; wherein I ſhall ſhew that of ſome Inſtruments rejected by him, there is a uſe abſolutely neceſſary.

The Inſtruments therefore that he begins with are three ſmall Quadrants of Braſs; the firſt of two foot, the ſecond of eighteen inches, and the third of one foot Radius. Each of theſe Inſtruments, he ſayes, were made ſomewhat larger then common Quadrants, to wit, of an arch of 110 degrees, which is to no other end, but only in order to ſhew the ſubdiviſions of each degree of the Quadrant, by the help of a new invented Perpendicular of Braſs wherewith each of them was furniſht. This Invention is by him highly extoll'd for moſt excellent and uſefull; and to that end is made uſe of for the diviſion of all his other Inſtruments, both great and ſmall. Hear what he ſayes of it: *Quiſcunque hujus rei* (to wit, the new way of ſubdividing the degrees of the Quadrant) *primus fuerit repertor, ſublimes profecto cogitationes exercuit, hoc ipſo ad congruentem effectum deducendo, & inter præſtantiſſima inventa meritiſſimo refertur, quod etiam minora Inſtrumenta remotis omnibus tranſverſalibus Lineis, in ſingula minuta eorúmque particulas minimas ſubdividi liceat.* He ſeems indeed both here, and elſewhere in many other places of his Book to be highly poſſeſt with admiration of the ſublimity, ſubtilty, and extream uſefulneſs of this invention, and ſeems very much concern'd that the Author thereof ſhould not certainly be known, but dares not father it upon any one poſitively. He ſayes that one *Benedictus Hedreus* in a Work of his which he publiſhed *Anno* 1643. about the new and accurate Structure of the Geometrical Aſtrolab, deſcribes it; but he gathers that he was not the Inventor himſelf, but rather that he got both this Invention and the whole Quadrant, which he deſcribes out of the Obſervatory, or rather Repoſitory of *Ticho Brahes* Inſtruments, for that it ſeems *Ticho* was the Inventor of this way of diviſion; and yet, as I noted before, he prefer'd the way by Diagonals much before it, whatever Reaſon *Hevelius* had to be of a contrary Judgment. What this way is I ſhall by and by explain. But in the mean time I am

ſorry

ſorry to find *Hevelius* joyning with *Hedreus* in the Opinion or Demonſtration, as *Hevelius* calls it, that the Sub-diviſions by Diagonals is not capable of a Geometrical demonſtration, eſpecially in leſſer Inſtruments, which have need of many Circles. I confeſs I underſtand not their meaning nor reaſoning, nor why it ſhould be leſs demonſtrable in leſſer then in greater Inſtruments; ſince 'tis very eaſily demonſtrable both in greater and leſſer Inſtruments, and as Geometrical as any other way of Diviſion whatſoever: the Diagonal Line being alwayes a piece of a Tangent Line, that is to ſay, the ſpaces between the Parallel Circles upon the Diagonals are alwayes to be in proportion to the difference of ſome Tangent Lines, and the different diſtance of thoſe Circles from the Center are alway in proportion of ſome Secants: And the way of finding what thoſe Tangents or Secants are, and conſequently what muſt be thoſe Diſtances of the Parallel Circles I mentioned briefly before, and ſhall now more fully demonſtrate. From which I will make it evident, that the Theory was not as *Hedreus* and *Hevelius* have ſuppoſed, uncapable of Calculation or Mechanical Demonſtration.

But firſt give me leave to ſhew you what way *Ticho Brahe* made uſe of to demonſtrate, or rather to find out the true Angle unto each equal Diſtance, which I find ſet down at the latter end of his Mechanicks, as a Supplement to the reſt. *Diviſionis puncta habentis tranſverſalia modus talis eſt, ut* 34 *exprimit figura in qua ſingula denominata per Lincolas in decem interſtitia æqualia diſcriminatum punctis notata ſunt, ſicque regula fiduciæ quodcunque horum inter obſervandum tranſiens ipſum minutum gradus, quod quærebatur promit aut aliquotam ejus partem, prout ab hoc vel illo puncto removeri diſcernitur. Ut vero hoc etiam demonſtratum hic addam ob ſciolos fortè quoſdam qui ea quæ non ſatis capiunt carpunt ſic habe.*

In Figura 34. *Sit* A *centrum Inſtrumenti ejuſque Semidiameter* A O, *aſſumitur autem* O I, *Particula in qua diviſio iſta per lineas tranſverſas fit ea proportione quæ eſt* 1 *ad* 48. *qualis in meis Inſtrumentis ut plurimum uſurpatur. Cúmque* A I *ponatur partium* 10000000000. *integri canonis majoris Rhetici, erit earundem* O I 208333333 *utpote pars quadrageſima octava radii Arcus* I E *ſit* 20'. *&* I V. 10'. *horum ſinus* 29088779 Y I. *Sinus autem ſecundus*

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In Figura 34. *Sit* A *centrum Inſtrumenti ejuſque Semidiameter* A O, *aſſumitur autem* O I, *Particula in qua diviſio iſta per lineas tranſverſas fit ea proportione quæ eſt* 1 *ad* 48. *qualis in meis Inſtrumentis ut plurimum uſurpatur. Cúmque* A I *ponatur partium* 10000000000. *integri canonis majoris Rhetici, erit earundem* O I 208333333 *utpote pars quadrageſima octava radii Arcus* I E *ſit* 20'. *&* I V. 10'. *horum ſinus* 29088779 Y I. *Sinus autem ſecundus*

eorundem

eorundem 42308. V Y. *qui additus* N V *quod æquale est* O I *facit* N Y 208375641. *In triangulo igitur* N Y I *ad* Y *rectangulo nota sunt duo Latera* N Y *&* Y I. *quare datur basis* I N 210396208. *una cum angulo* N I Y 82°. 3'. 10". 47"'. *cui additus* Y I A 89°. 50'. *conficit* N I A. 171°. 53'. 10". 47"'. *Basis verò* N I *in triangulo rectangulo* N V I *dividatur in decem partes æquales ut conveniant uni minuto* 21039621 *repræsentatæ per* I B. *Moxque in triangulo obliquangulo* B I A. *dantur duo latera* I B *&* I A. *radius, una cum angulo* B I A, *qui idem est cum* N I A 171°. 53'. 10". 47"'. *prius reperto: quare innotescit angulus* I A B 1'. 1". 7"'. *qui tantummodo* 1'. *esse deberet, ità ut major sit saltem* 1". 7"'. *differentia sanè insensibili: similiter si* F I *assumatur, novem particularum erunt ea* 189356587 *habebimusque rursus triangulum* F I A *in quo dantur duo latera* F I *modo dictum una cum radio* I A. *& angulo* F I A *ab iisdem comprehenso velut antea exurgitque angulus* I A F 9'. 1". 6". *qui debebat esse* 9' *exactè deficiente in ultimo minuto* F N. 1". 6"'. *Porrò ut circa medium idem tentetur quod nunc apud extremitates fecimus inveniuntur eadem qua antea primo Angulus* I A H 5'. 3". 6"'. *abundans* 3". 6"'. *Secundo Angulus* N A H 4'. 56". 55"'. *deficiens* 3". 5"'. *Patet itaque quod maxima differentia, sive adjectiva, sive ablativa in hac pragmatia proveniat minimum quid ultra* 3". *quam subtilitatem visus acumen discernere in quocunque tandem instrumento nullatenus sustinet, qua etiam per se otiosa est, quare frustra nodum in Scirpo quærunt, si qui hanc nostram satis accuratam distributionis formam cavillari præsumant.* By which 'tis evident that *Ticho* understood an inequality, and what it was, and that it was insensible, and so not to be regarded. Now 'tis to me very wonderful indeed that *Ticho* having thought of a way of calculating this inequality, should not think of an easie expedient of reforming it by putting the Parallel Circles at unequal, but their due proportionate distances. And 'tis much more strange that *Hevelius* should still affirm it to be a way not Geometrical: For to any one that considers this proportion, the inclination of a Diagonal Line being given to find the true distances of the Parallel Circles that shall divide any assignable part thereof in any proportion assigned: Nothing can be more easie: and for more expedition use may be made of the Table of Natural Tangents which is ready calculated to hand. For instance: Let B C represent a Diagonal Line subtending an angul

gul of 10°. at the Center A, produce the ſaid Line BC to F, and let fall a Perpendicular, from the Center A to E. Suppoſe then the Angle at B to be one Degree, then is BE the Tangent of 89°. to the Radius AE. and EC is the Tangent of 88. 50'. and the differences between the Tangents of 88 50, 88, 51. 88, 52. 88, 53. 88, 54. 88, 55. 88, 56. 88, 57. 88, 58. 88, 59. and 89. gives the Diſtances of the ſeveral Circles, C. 1 2 3 4 5 6 7 8 9 B. deſired.

Since the Reading of this Lecture, Dr. *Wallis* hath alſo deſcribed another way of finding theſe Diſtances, which he hath communicated in a Letter to *Hevelius*, and I have prevailed with the ſaid Doctor to permit it to be here printed, being very ingenious and accurate, and proceeding by a differing method.

Dr. *Wallis* his Letter to *Hevelius*.

—*SED & eſt cur communi omnium Literatorum nomine rebus præſertim cælicis addictorum reddam gratias, tum ob immenſos in tanto apparatu ſumptos erogatos, tam prætioſum conquirendo ſupellectilem Aſtronomicam, graphice hic deſcriptam, tum ob indefeſſos labores, inſomnes noctes dieſq; occupatiſſimos cæleſtis acquirendis obſervationibus impenſos; quarum vim ingentem, Theſauram ſupra aurum & margaritus prætioſum erudito orbi jam ante dederis, plura daturus indies, verum non eſt ut ſperem me verbis æquare poſſe tua merita, qui ex privatopenu ſumptos plane Regios erogaſti; onuſq; ſuſcepiſti non infeliciter, Herculeis Humeris (ne Atlanteis dicam) formidandum.*

Operis partem maximam jam evolvi, miratus inibi tanta molis Inſtrumentorum ingenioſiſſimum regimen, & ſubtiliſſimam diviſionum adminiſtrationem, cum pari diligentia conjunctam in Regulis & Dioptris ſolicite curandis, & quidem ſi hoc deeſſet reliquus in caſſum cæderet labor; quippe exiguus & vix evitabilis in Regulis aut Dioptris error, totum Inſtrumentum vitiaret, omneſq; inficeret obſervationes, ſed ſingulis immorari non licet, unum tamen eſt quod attingam breviter, nempe diviſiones per Lineas Diagonales, circulos in limbo concentricos oblique ſecantes. Hanc dividendi methodum jam diu receptam, ipſe retines & quidem merito, circulosq; hos concentricos æqualibus intervallis disjunctos habes, quod quamvis in exiguorum aut etiam mediocrium Inſtrumentorum limbis

limbis latioribus aliquid erroris possit inducere in tuis tamen tantæ amplitudinis Instrumentis cum limbis exiguæ latitudinis (quod & tu recte mones) nihil quicquam erit discriminis quod in sensus occurrere possit. Hac tamen occasine libet hic subjicere, quod ea de re jam olim (circa A. 1650. *aut* 1651.) *meditatus sum, atq; apud adversaria mea nunc reperio: nempe si quis vellet minoris Instrumenti limbum latiorem Lineis Diagonalibus sic dividere, quibus intervallis oporteat concentricos illos circulos disponere ut angulos invicem æquales designarent illæ cum tranversali intersectiones calculo Trigonometrico determinare.*

Divisio arcus in limbo quadrantis (aliusvé ejusmodi Instrumenti) per circulos concentricos & rectam Diagonalem, sit latitudo limbi (RL=) L, *Radius circuli intimi* (AR=) R, *extimi* (AZ=AL=) L+R=Z *continentes angulum* (RAZ=) A. *dividendum in partes quotlibet æquales (quarum numerus* n) *rectis* a,b,c, *&c. (quarum longitudo quæritur) facientibus ad* RZ *diagonalem, angulus* $\alpha, \beta, \gamma, \delta$, *&c. adeoque angulus* RA a $= \frac{1}{n}$ A, RA b $= \frac{2}{n}$ A. RA c $= \frac{3}{n}$ A, *&c. sitque* ARZ=O & AZR=V. *Datis ergo crucibus* R, Z *cum angulo contento* A. *(adeoque reliquorum summa* O+V) *inveniuntur reliqui* O *obtusus* V *accutus.) Nam* Z+R. Z−R :: *Ita tangens* $\frac{O+V}{2}$. *tangentem* $\frac{O-V}{2}$ & $\frac{O+V}{2}+\frac{O-V}{2}=O$. *deinde cognitis angulis* O & $\frac{1}{n}$ A *(adeoque reliquo* α) *cum trajecto latere* R *habetur latus* a. *nempe sin* a. R :: *sinus* O. a. *& pari modo ex cognitis.*

$$\left\{\begin{array}{l} O\ \frac{2}{n}\ A. \\ O\ \frac{3}{n}\ A. \\ O\ \frac{4}{n}\ A. \\ \&c. \end{array}\right\} \textit{habentur} \left\{\begin{array}{l} b \\ c \\ d \\ \&c. \end{array}\right.$$

Praxis sit R=1. L=0, 2. Z=1, 2. A=10'. *ergo* O+V= 179°. 50'. $\frac{O+V}{2}$=89°. 55'. *tum* Z+R=2, 2. Z−R=0, 2. :: $\frac{O+V}{2}$=687, 5488683. 62, 5044427= *tang.* $\frac{O-V}{2}$ *cui respondet angulus* 89°. 5'. 0''. 17'''. *proxime. Ergo* $\frac{O+V}{2}+\frac{O-V}{2}=0$ = 179°. 0'. 0''. 17'''. *fere cujus sinus* 0, 0174511. *nempe idem qui sinus* 0°. 59'. 59''. 43'''.

Deinde secandus sit A in 10 *partes quarum quælibet sit* 1'. *quæruntur igitur* a,b,c,d,e,f,g,h,i, *nempe.*

Sin.

			1.00000=R	
Sin.α(0° 58′59″43‴)0.0171603.	R=1:: *Sin* O=0.0174511.	1.01694=a.	1694
Sin.β(0 51.59.43.)0.0168694.	R=1:: *Sin* O=0.0174511.	1.03448=b.	1754
Sin.γ(0 56.59.43.)0.0165780.)	0.0174511(	1.05264=c.	1816
Sin.δ(0 55.59.43.)0.0162877.)	0.0174511(	1.07144=d.	1880
Sin.ε(0 54.59.43.)0.0159969.)	0.0174511(	1.09091=e.	1947
Sin.ζ(0 53.59.43.)0.0157060.)	0.0174511(	1.11110=f.	2019
Sin.η(0 52.59.43.)0.0154152.)	0.0174511(	1.13206=g.	2196
Sin.ϑ(0 51.59.43.)0.0151243.)	0.0174511(	1.15383=h.	2264
Sin.ι(0 50.59.43.)0.0148335.)	0.0174511(	1.17647=i.	2353
		1.20000=Z.	

Praxis altera sit R=1. L=0,1. Z=1,1. A=10″. *ergo* $\frac{O+V}{2}$= 179, 50. $\frac{O+V}{2}$=89°. 55′. *cujus tangens* 687, 5488693, *&* 2, 1. 0,1 :: 687, 5488693. 32, 7404223½= *tang.* 18°. 15′. 1″. 57‴¼ $\frac{O-V}{2}$ *ergo* $\frac{O+V}{2}+\frac{O-V}{2}$=O=178°. 10′. 1″. 57‴¼. *cujus complementum ad semicirculum* 1°.49′.58″. 2‴¾. *cujus sinus* 0,0319827. *ergo*

		(1.00000=R		
Sin α=1°.48′.58″.2‴¾)=316920)	319827	(1.00918=a	918	16
Sin β(1.47.50.2¾)=314013)	319827	(1.01852=b	934	17
Sin γ(1.46.58.2¾)=311103)	319827	(1.02803=c	951	19
Sin.δ(1.45.58.2¾)=308198)	319827	(1.03773=d	970	19
Sin.ε(1.44.58.2¼)=305290)	319827	(1.04762=e	989	18
302343)		(1.05769=f	1007	20
299475)		(1.06796=g	1017	21
296567)		(1.07843=h	1068	21
293660)		(1.08911=i	1089	
290752)		(1.10000=k	=Z	

Hactenus adversaria, ubi duos casus expendimus, nempe cum latitudo limbi ponetur pars quinta & pars decima Radii brevioris, & angulus dividendus 10 *minutâ prima tanta fere* ἀκριβεῖα, *quantum feret vulgaris canon Trigonometricus: & quidem ultima unitas in ambiguo est nunc justo major nunc justo minor. Radium autem (ut ego soleo) facio* L *(non ut plerumq; fit* 10000000.) *quo omnes multiplicationes & Divisiones per Radium faciendæ præcidantur: Adeoq; sinus habeo pro partibus decimalibus, quibus itaq; cum opus est, ciphras præmitto quo de unius integri loco constet.*

 Simili

Simili proceſſu utendum erit mutatis mutandis ſi latitudo limbi ſumatur in alia quavis proportione ad Radii longitudinem. Sed commodius erit (ad vitandam moleſtiam toties quærendi partem proportionalem) ut ſumatur angulus ○ commodæ magnitudinis (juſtis minutis primis determinandæ abſq; annexis ſecundis tertiiſve) atq; ita quæratur Radii maximi Z longitudo, eodem modo quæ Reliquorum a, b, c, *&c. puta ſi in praxi poſteriori ſumpto ut prius* R=1 *& angulo* A=10′ *ſumatur angulus* ○ *non qui illic prodit* 178, 10′, 1″, 57‴ $\frac{1}{4}$ *ſed potius* 178. 10′. *cujus complementum ad duos Rectos eſt* 10. 50′. *hujus ſinus in ipſo canone habetur* 0,0319922 *& reliquorum item* α, ς, γ, δ, *&c. ſinus ſimiliter ibidem habebuntur, ut una tantum diviſione opus ſit pro ſingulis exhibendis ipſaque Radii* Z *Longitudo habetur non quidem preciſe ut prius*, 1, 1 ; *ſed proxima (quæ itaque ſumenda erit)* 109996 *nempe.*

			(1.00000=R	917.17
Sin. α (=1.49)	=317015)	319922	(1.00917=a	934.18
ς =1.48)	=314108)	319922	1.01851=b	952.17
&c.	311200)		1.02803=c	969.19
	308293)		1.03772=d	988.19
	305385)		1.04760=e	1007.20
	302478)		1.05767=f	1027.20
	299570)		1.06794=g	1047.20
	296662)		1.07841=h	1067.21
	293755)		1.08908=i	1088.
Sin. κ (=1.40)	=290847)	319922	1.09996=k	=Z

ſimiliter omnino res ſuccedit ſi ſumptis Radiis R L cum angulo A quæramus V & Radios intermedios, aut ſumpto Radio L cum angulis A V quærantur R & Radii intermedii.

Verum ſi limbi latitudo ſit Radii non niſi pars trigeſſima quadrageſſima, quinquageſſima aut adhuc minor, atq; angulus dividendus non quidem 10 *minuta prima ſed totidem ſecunda, aut minor adhuc, ſubtilior res eſt quam ut canon vulgaris Trigonometricus hic adhibeatur ; & quæ omnem ſenſum fugit, ipſiq; circuli concentrici diſtantiis æqualibus quantum ſenſu poſſumus diſtinguere invicem diſjuncti : quippe unius pollucis pars milleſima vel dum decies aut centies milleſima minor eſt diſcrepantia quam ut ſenſu percipi poſſit. Sed nimius ſum in re levi felicem itaq; exeuntem animum tibi comprecatus longa ſequentium ſerie contrivandum, valere jubeo.*

But

But to proceed. In the next place I think it will be ſuffiicently plain, to any one that ſhall try both the ways, that the Diviſions are by Diagonals much eaſier diſtinguiſhed by the eye, then by this way ſo applauded by *Hevelius*, and therefore I cannot chooſe but conclude with *Hevelius*, (pag. 140.) though to a quite differing end and ſenſe: *Sunt igitur ſplendidiſſimæ tantum ſpeculationes mentisq; ideæ quæcunq; de* Nonianis *vel* Hedrianis *Diviſionibus proferuntur.* But becauſe perhaps there may be ſeveral perſons that have not yet peruſed this Book of *Hevelius*, nor that of *Benedictus Hedreus*, printed in 1643. nor *Tycho*'s Mechanicks, of a much longer ſtanding, and thence may perhaps not ſo well underſtand what this way of ſub-dividing is; give me leave a little to explicate it, and ſhew you plainly what it is.

The way then as it is deſcribed by *Ticho Brahe*, and aſcribed by him to *Petrus Nonius*, that excellent Spaniſh Mathematician, who publiſht it in his learned Book, *de Crepuſculis*, ſuppoſing it alſo to have been heretofore uſed by *Ptolomy*, but (as *Ticho* is of opinion) without much reaſon, is this; *Ut ducantur intra extremum quadrantem alii minores numero* 44. *ſucceſſive ſeſe comitantes, quorum extimus in* 89. *ſequens in* 88. *tertius in* 87. *& ſic deinceps donec ad ultimum & intimum perventum fuerit qui* 46. *portiones habebit.* To which Deſcription publiſhed in his *Mechanica*, he adds in the ſecond Book, *de Mundi Ætherei recenſioribus Phenomenis*, pag. 461. *Altera Diviſio ad Clariſſimi Mathematici* Petri Nonii —— *imitationem per plures quadrantis arcus introrſum deſcriptos & diverſimode ſubdiviſos procedit. Etſi autem in hac ipſa imprimis ingenioſa* Nonii *inventione, aliquid auctuarii loco expeditius à nobis additum eſt, ita ut exterior arcus in plurimas portiunculas dividatur; neque is ordo aut numerus arcuum ſeſe introrſum concomitantium, quem ille præfinivit ſed multo expeditior & perfectior obſervetur, tamen quia hæc ſubtilitas cum ad praxin deventum eſt plus habeat laboris quam fructus, neq; id in receſſu præſtet quod prima fronte pollicetur, ut alibi plenius oſtendimus, idcirco apud nos dudum in uſu eſſe deſiit.* [See more of this, pag. 62. *Epiſtolarum Aſtronomicarum.*]

From which way of Diviſion, this of *Hevelius* (which he aſcribes to *Hedreus*, but is more properly aſcribable to *Pierre Vernier*, as I ſhall afterwards ſhew) is ſomewhat different,

and possibly might be the same that *Tycho Brahe* contrived to compendifie that of *Nonius*.

The way then is this, described by *Hevelius*, pag. 141: *Quadrantes contractiores ita à me sunt adornati, ut limbos eorum tantum in integros & semigradus distinxerim; quæ ut hæc distinctio non nemini admodum rudis videatur, sufficit tamen affatim commonst andis singulis minutis primis; dummodo perpendiculi ex centro appensi extremitas limbum stringens in certas particulas sit subdivisa, imo quod magis de quo non nemo sane mirabitur, non solum hæc rudior limbi subdivisio sufficiens exhibendis singulis minutis primis sed etiam pro denis quinis quinetiam singulis secundis in majoribus organis si videlicet nostrum Instrumentum directorium adhibeas. Oportet ut inferior illius pars curiosissime & levissime sit limata & levigata, ut limbum totum æquabilissime quidem tangat, sed nullibi nimis adhæreat; tum quovis loco liberrime pendeat atq; divisionis tam quadrantis quam perpendiculi observator rite discernere valeat. Dividitur autem istud perpendiculum hac ratione, si videlicet spatium* 31 *semigraduum in limbo perpendiculi accuratissime denotes; idq; primum in tres æquales partes, rursum quamlibet trientem in decem dividas; atq; ita obtinebis spatiola paulo admodum ampliora quam spatiola unius semigradûs, quia intercapedo* 31 *partium in* 30 *transmutata necessario fiunt modice ampliores. Attamen si divisiones perpendiculi ad limbum quadrantis accedant circa extremitates perpendiculi, discrepantiola illa divisionum ab invicem vix ac ne vix cognoscitur; circa medietatem vero perpendiculi satis evidenter. In medio limbo perpendiculi & divisionum parvulus index & quidem inter* 15 *&* 16 *spaciolum constituitur pro discernendis integris & semigradibus; quos accurate dictus index indicat, quando totum spatium perpendiculi in* 30 *partibus divisum in ipso limbo quadrantis spatium* 31 *partium exquisite subtendit. Ea tamen expressa lege si totum Instrumentum absolute ab omni parte sit constructum; quando vero iste index pauxillum promotior existit integro aliquo vel semigradu certissimum est indicium, observationi minuta quidem adhærere aut integro aut semigradui adnumeranda, si index huic vel illi vicinior est. Cognoscitur autem minutorum numerus ex eo, quando lineola aliqua divisionum in perpendiculo cum una aliqua in limbo quadrantis prorsus in unam eandemq; coincidit rectam. Nunquam enim nisi unica lineola in perpendiculo cum altera in quadrante, si exquisite peracta*

sunt

ſunt omnia omnino concurrit. In iſto igitur utriuſq; lineolæ concurſu ubi una eademq; videlicet conſtituitur linea eſt terminus ipſorum minutorum vel integro gradui vel ſemi gradui adhærentium.

This ſame way is alſo made uſe of by *Hevelius*, for the Diviſion of all his larger Inſtruments, as well as for the Diviſion of this ſmaller, by fixing it upon the Perpendicular, as he afterwards mentions, *cap.* 15. *pag.* 307. where he alſo gives a fuller deſcription of it, to which I refer the Reader.

The way indeed is exceeding ingenious, and very much improved by *Hevelius*, but yet at the very beſt it is very difficult, both to make the Diviſions, and much more difficult to diſtinguiſh them, as may be plainly enough ſeen even by that very Specimen publiſhed by *Hevelius*, in the firſt and ſecond Figure of the Plate T. eſpecially if it be viewed with a magnifying Glaſs or Lens; and I do wonder that *Hevelius* did not all this while think of making uſe of a Lens, to make the Diviſions and Diſtinctions appear more plain, without which Seconds are not to be diſtinguiſhed, by thoſe kinds of Diviſions even in an Inſtrument of 10 foot Radius, and by the help of it they may be made and diſtinguiſhed, in Inſtruments of a quarter that bulk, as he may find, if he pleaſe to make uſe of the ſhalloweſt Object-Glaſs of that Microſcope which he had from *London*; he may, I ſay, by looking upon the Diviſions of the firſt and ſecond Figures of the Table T. with his Microſcope, plainly detect how far thoſe Diviſions are ſhort of accurateneſs, and how many faults and inequalities the naked eye and unmachined hand do commit.

It is therefore one of my ways for dividing and diſtinguiſhing Diviſions, to make uſe of one, two, or three Lenſes, whereby not only the eye is very much eaſed, but the judgment is very much augmented, and the hand directed, as I ſhall afterwards explain, when I come to ſhew ſome particular ways of making Diviſions.

But becauſe this *Benedictus Hedreus*, from whom *Hevelius* affirms he received this invention of dividing the Limb of the Quadrant, was not ſo ingenuous as to confeſs that he received this invention from another, and becauſe perhaps the Book being ſmall, may have been long ſince loſt and forgotten, having accidentally

accidentally met with one, I shall acquaint *Hevelius*, that one *Pierre Vernier* (as he calls himself) *Capitain & Chastelain pour sa Majesté au Chasteau Dormans, Conseiller, & General de ses Monnoies au Conté de Bourgongne*, printed at *Brussels*, by *Francis Vivien*, 1631. (to wit 12 years before *Hedreus*) a Treatise in French, which he calls, *La construction l'Usage & les Proprietes du quadrant nouveau Mathematique, comme aussi la construction de la table des sinus de minute en minutes successivement par un seul maxime. De plus un abregé desdicts tables en une petite demi page avec son usage: & finallement la methode de trouver les angles d'un triangle par la cognoissance des costez & les costes par les angles sans l'ayde d'aucune table.* In which he hath at large and very plainly described this way of dividing the Quadrant, to what accurateness is desired, and pretends it to be, as possibly it was, an invention of his own.

But to return where I left to *Hevelius* his Division on the Quadrant by the help of the Brass-arm, I say, against this way, besides what I have already mention'd, I have a second Objection, and that is, that it requires a most exceeding great curiosity and care to make that Metal Pendulum or Plumb of Brass, so as to be exactly of equal weight and make on both sides of the supposed middle Line, for if it be not so, it may easily vary not only some Seconds, but even some Minutes from its exact Perpendicularity, and if so, 'tis to little purpose all the former curiosity about Subdivisions.

Thirdly, The Perpendicular ought alwayes to be kept very clean from Dust, for if a little more Dust settle on the one side then on the other, the Perpendicularity will be vitiated, and all the curiosity else about the Observation will be lost.

Fourthly, If the Pin on which this Brass Perpendicular hangs be not of some bigness, it may easily warp, or bend; and if it be of a considerable bigness, it will not move easily, and consequently the Plumb will not hang tender, but stiff; in both which cases it can be of no use in the World for Astronomical Observations. Further, if it hang loose upon the Center, which it must do to hang tender, then there will lye as material an Objection against it, for its not moving true upon the Center of the Instrument; and therefore upon the whole matter I conclude it to be an Invention indeed of great sublimity and subtleness

ſubtleneſs, but of little or no uſe for Aſtronomy, to which *Hevelius* applies it. He had much better therefore have been content to have followed *Tycho Brahe*, and made uſe of a common Plumb Line and Diagonal Diviſions, where there is occaſion for them, for that is true and practicably capable of exhibiting the Subdiviſions of a Degree, as Minute, as are neceſſary to common Sights.

In the next place, before he leaves the Deſcriptions of theſe three ſmaller Quadrants, he mentions an Invention of his whereby he fixes the Quadrant in any altitude, and eaſily moves it ſteadily into any poſture deſired by the help of Screws. This Invention of his own contrivance he doth indeed very highly applaud, inſomuch that he believes no good Aſtronomical Obſervations can be made without it. But he muſt pardon me if I am not altogether of his mind; I grant indeed the thing is exceedingly convenient, in compariſon with any yet uſed, if it be well made, and that the way of applying it to the Quadrant be very facil and eaſie. But 'tis not alway ſo neceſſary, but that Obſervations may be as conveniently made without it, as I ſhall afterward ſhew, in the Deſcription of the moveable Axis, for continuing the Inſtrument in the Plain of the Object, whether a Diſtance or an Altitude be to be taken.

In the next place he proceeds to deſcribe his large Quadrant of Braſs adjuſted ſo as to take Altitudes and Azimuths, of which he makes a full and particular deſcription; but the moſt conſiderable thing that is new in it is, that inſtead of a Screw uſed by *Tycho* for lifting and moving the Arm with Sights, he makes uſe of two Lines poys'd with Plumbets, by the pulling of this or that of which he is able to raiſe or ſink the Ruler with Sights, all the reſt of the contrivance being to make it ſtand perpendicularly in any Azimuth, which I think may be done to greater certainty with leſs trouble, by a way I ſhall afterwards ſhew: As an Eſſential part of this Inſtrument, he takes occaſion to give the deſcription of the Turret or Obſervatory which he built for it, and the ſeveral contrivances about it, which I now omit.

The uſe he made of this Inſtrument was for the taking the Meridian Altitudes of the Sun, of which he affirms to have taken a very great number, eſpecially ſuch as were of princi-

pal

pal uſe for the regulating the motion of the Sun: Such as the Solſtitial and Æquinoctial Altitudes, of which I hope we may expect an account in the ſecond and third Part of his *Machina Cœleſtis*. I know not to what exactneſs he hath proceeded in taking his Meridian Altitudes of the Sun; but had he proceeded in the way by Teleſcopes, he might have taken all his Altitudes of that kind to a ſingle Second, with great eaſe and certainty.

And upon this occaſion I hope it will not be unacceptable to my Aſtronomical Reader to hint a very expeditious and exceeding accurate way of making a Catalogue of all the viſible, as well as the moſt conſiderable Teleſcopical Stars of the Heaven. For the doing of which there will not need a tenth part ſo much time as for the other wayes that have already been made uſe of, and yet will very much exceed them all in accurateneſs and certainty. The way then in ſhort is nothing but this: Let there be made a very large mural Quadrant, or rather Semicircle, of 30 foot Radius, fixed exactly in the Meridian againſt a Wall made of ſquared Stones, well joynted and cramped together, and ſetled on a foundation very firm and ſolid, to prevent all manner of ſlaking and ſwarving. Let the rim of this be made of Braſs Plates, ſtayed in their due poſture by cramps or bars of Iron fixed in the Wall, by running them with Lead: then having divided this Semicircle into 180 Degrees, and ſubdivided each Degree by the help of Diagonals, on a flat and well poliſht Plate of Glaſs, according to the way I before deſcribed into Minutes and Seconds: adapt to it a 30 foot Teleſcope, ſo that the Tube ſhall not warp, nor the Glaſſes deviate out of their true poſture; the Focus of the Object Glaſs make to be exactly upon the edge of the Braſs Limb, ſo that by the help of the Eye-glaſs, which is a deep Convex, the punctual place or altitude of a Star to a quarter of a hairs breadth, even to Seconds of a Minute, may be diſcover'd: the trouble of dividing this Quadrant will be no more then of one of an ordinary ſize, the ſubdiviſion of one Degree ſubdividing and examining all the reſt. The way of making the Tube of the Teleſcope ſo as not conſiderably to bend, may be done ſomewhat after that way of ſtiffning the Tubes of very long Teleſcopes, which I communicated to *Hevelius*, and you will find

at

at large deſcribed in this Treatiſe of *Hevelius*: Save only, that inſtead of Ropes which I firſt made uſe of, *I* rather commend ſo many Braces of Wood. Now though notwithſtanding all the Diligence that can be this way uſed, the Tube do ſomewhat bend in the middle, yet it can be of no manner of ſignificancy as to the vitiating the Obſervation; ſince firſt, the Object Glaſs always ſtandeth in the ſame poſture as to the Center, and ſecondly, the Focas thereof is exactly in the edge of the Limb.

Further, to prevent the inconvenience of looking up or in any other uneaſie poſture by the help of a reflex Metal one may always look Horizontally, that is, perpendicularly to the plain of the Wall or Mural Quadrant. And to prevent the trouble and labour of moving or lifting the Tube by the help of a long yard poyſed upon Centers on a Frame before the ſaid Inſtrument, both the Tube & Arm for the Sight, and the Seat on which the Obſervator ſits, may be counterpoiſed, ſo that by turning a Windle, he may eaſily raiſe himſelf with the Tube to any poſture deſired. The Object Glaſs is juſt before the Center, and the Eye Glaſs looketh directly on the Diviſions of the Limb, and there is nothing to ſtrain or ſtir the Inſtrument it ſelf, nor can the warping of the Tube, if there ſhould be any, have any effect on the Obſervation: Of this I may ſay more on another occaſion. By this means (in one Nights Obſervation) the Declinations of ſome hundreds of Stars may be taken to a Second by one ſingle Obſervator, having only one or two Aſſiſtants to write down the Obſervations as faſt as made. And at the ſame time the right Aſcenſion of every one of them may be taken by the help of a very accurate Compound-circular Pendulum Clock, which I ſhall elſewhere deſcribe, denoting even to $\frac{1}{10}$ of a Second of time the appulſe of the Star to the Meridian: There needs indeed great exactneſs in every part of this Apparatus, and 'twill not be done without a conſiderable charge, and much labour and diligence in the performance thereof; but if we compare it with the methods and wayes that have been hitherto uſed, we ſhall certainly find that the Obſervations will be near 30 times more accurate, the charge not a quarter, and the labour not near a tenth part ſo much as in other wayes made uſe of by *Tycho* and *Hevelius*. And though it may be objected againſt this way (which indeed may be much more ſo againſt

any other) that the refraction of the Air will considerably vary the Declination of such Stars as are very far South, yet since the same Instrument affords a way beyond any in the World for the discovering the several Refractions of the Air at several Altitudes above the Horizon, to the accurateness of a Second, by taking the Altitude of such Stars as never set in the North, in the greatest and least Altitude above the Horizon; a Table of such Refractions will easily rectifie the Declination of the other Stars to as great accurateness. This Subject doth deserve a much larger and more particular Description of every Branch thereof, and the Incouragement of some Prince, whose Name and Honour will thereby be Registred among those glorious Celestial Bodies to all Posterity, and the succeeding Learned World will be obliged to celebrate his memory. But I fear this Age will hardly yeild another *Alphonsus*, another *Ticho*, or another *Hevelius*, who have not spared to expend their utmost Indeavours in performing this task, though by other methods. But leaving this for another time, I shall proceed.

In the third place then he goes on to describe his great Horizontal voluble Brass Quadrant, of which he says, he does not believe that ever the like was made by any, if the splendid *Apparatus* and the whole Fabrick thereof be consider'd. It is in Diameter six foot and an half, and serves, as he affirms, to take Altitudes to Seconds; but yet he is necessitated to allow, that it is short both of *Ticho*'s large wooden Quadrant, and of his large mural Quadrant; nor do I see any reason why *Ticho*'s mural Quadrant should not take Meridian Altitudes somewhat more accurately, since I believe his Sights every whit as good, and his Divisions altogether as exact; what he might fail in diligence, I cannot say. I do believe this Instrument to be an exceeding good one of the kind, and that he hath from much practice and experience found out many contrivances, in order to the making it convenient to make Observations, and he hath not spared for cost, pains, study and industry, for the compleating thereof; but still whether he be arrived to the greatest perfection, or to so great as to take Altitudes to Seconds, seems to me very dubious, and if he made use of the Sights before-described, wholly impossible. For first, a Degree upon the Limb is but about $\frac{1}{3}$ of an inch, and consequently a Minute is

but

but the 50th. part of an inch, and a Second but the 3000th. part of an inch, which he that can diſtinguiſh with his naked eye, hath better then I, or I fear, any man now living. Short-ſighted men, I grant, can do much toward the diſtinguiſhing very minute Diviſions, by being able to bring the Object very near the eye, but the moſt ſhort-ſighted muſt be yet very much ſhortned by Glaſſes, before he will be able to diſtinguiſh the 3000th. part of an inch, and when he hath diſtinguiſhed it, which he may poſſibly do with a Microſcope, how will he diſtinguiſh of the Penumbra, which is not certain even to a Minute? And though it may be ſaid, it is the ſame, round the Circle, and the Circle is the true bigneſs of the Sun, ſo that if a Circle of a bigneſs, anſwering to the Diameter of the Sun, and the Diſtance of the lower Sight from the upper be deſcribed on the lower Sight, it muſt bound the Limb of the Sun, and that conſequently it will be eaſie to diſtinguiſh when that Circle is perfectly fill'd with the figure of the Sun, admitted through the hole in the upper Sight. I anſwer, That this ſeems very probable and eaſie, and is indeed believ'd and aſſerted ſo by Optical Writers: But yet 'tis quite otherwiſe; for not to mention that there is confeſſed by all, that the Penumbra of this Circle muſt be as big at leaſt as the Diameter of the hole above, through which it is trajected, which cannot be leſs then a Minute; I ſay, that experience doth demonſtrate that it is quite otherways, and that the Limb of this Image painted on the lower Sight is terminated with a Penumbra, which is ſometimes five or ſix times bigger then the Diameter of the hole, and which is yet ſtranger, the ſmaller the hole be, the bigger is the Penumbra, and the bigger (to a certain Degree) the leſs, but there is no bigneſs which will take it off quite, and the Diameter of the Sun that way taken, is ſometimes bigger and ſometimes leſs then it ought, and that to a very conſiderable quantity: Of which, and ſeveral other very ſtrange proprieties of Light, I ſhall hereafter ſay more on another Subject.

But to proceed. That he hath made this Inſtrument his chiefeſt, you may perceive by his pathetical deſcribing thereof; for he ſays of it, *pag.* 184. *Ad commodiorem hujus quadrantis uſum tot ac tot adminicula recens excogitata atq; huic organo applicata fuere, ut neſciam a quibus primum inchoare debeam. Imo*

etiamsi vel maxime velim, nullo tamen modo omnia & singula adeo perspicue vel delineare vel describere potero, ut universi præprimis qui similia haud ipsimet oculis usurparunt quævis recte ac plane intelligant, quinetiam credas velim utut aliis sunt attentiores atq; hujus rei bene gnaros, aliquoties sane hocce Instrumentum visuros antequam dimidiam tantam partem debite animadvertant ac plenissime comprehendant. Quippe & verum fateor nec ipse ego, licet singula ex meo solo cerebro prodierint ac confecta fuerint, possem adeo distincte tibi eum sub aspectum ponere nisi mihi hocce organum sub oculis assidue versaretur. Nihilotamen minus dabo operam, ut quantum fieri poterit, dilucide omnia proponam, reliqua veri exercitatis cæli metaloribus ulterius rimanda & perquirenda commit am, &c.

And so he proceeds with the Description of this Quadrant, and the *Apparatus* about it, and first, he tells us of the weight of this Instrument, that it was 80 *l.* Next, of the shape of the Turret in which it was fixt, which is indeed very convenient and ingenious, it being so contrived, as to be voluble or convertible upon Truckles, having one only side open, and inclos'd on all sides else, so that neither the Observator nor the Quadrant was much expos'd to the injury of the weather, which is indeed of no small use in Astronomical Observations. But this may be done many other ways also. He tells us further of the admirable and prodigious use of Screws, in order to the setting and fixing the Quadrant. Next, As to the giving a motion to it, in order to follow the Sun and fixed Stars in their diurnal motion. Thirdly, As to perform all the Subdivisions of a Degree, not only into Minutes but into single Seconds. To all which I say first, As to the use of the small Hand-screws, I do grant, that in some cases they may have their conveniency, as to the moving and staying the Instrument. But then since he is fain to make use of two Screws, whereby both the hands must be imploy'd to manage these Screws, I judge them too troublesom for that use, and that there is a much better way, whereby the Quadrant being once set into the Azimuth of the Stars, it shall continue to be so, and to move along with it, without any trouble to the Observator, so long as the Observator hath occasion to have it remain so, which (that I may hint that only now by the By) is a

small

ſmall Automaton, which ſhall continue it for many hours exactly, in the Azimuth of the Star deſired, of which more hereafter.

Next, Whereas he affirms this way capable to ſhew Seconds as well as Minutes, I grant it may be capable; but then I muſt further affirm, that he hath not at all ſhewed how that can be done, nor is it indeed feaſible in his way, for he ſhews us not any way how to ſet it, that is, fix it certainly to any Degree: Now if he be not ſure in the fixing it exactly to a Second, upon that Degree where he would begin his Diviſion, 'tis a vain thing to be ſo accurate in the other Dimenſion, for he cannot be more certain, (let him be never ſo curious in the Subdiviſion with his Screw) then he is certain in the firſt fixing of his Screw to the Degree, for whatever he varies from the Degree in the ſetting, he varies at leaſt as much in the Subdiviſions, and conſequently unleſs that be ſome ways taken care of, which I do not find, 'tis a nicety without uſe.

To conclude therefore, I ſay, the Frame of this Inſtrument is extraordinary good, and by the help of ſome additions, as to the Sights, Diviſions, Perpendicular and Erection, might be made as good as need be deſired for any uſe in Aſtronomy, and 40 times better then what it is now made and deſcribed by *Hevelius*, or then any I have yet heard of to be made in the World. But as it is, it is not more exact then the large Inſtruments of the Noble *Ticho Brahe*, which he uſed 100 years ſince, and much ſhort of his mural Quadrant, for taking Meridional Heights.

He proceeds to the Deſcription of his new and large Braſs Sextant of ſix foot Radius: The Sights and the Diviſions thereof are in nothing differing from thoſe of the Quadrant, nor do I find any thing very conſiderable in the Deſcription thereof; it was made uſe of by two perſons in the ſame manner as the former Sextant, and like that of *Ticho*; but what grand inconveniences do attend that way of Obſervation, I ſhall afterwards ſhew, when I come to explain how one perſon alone may be able to do it with leſs trouble by half, and ten times more exactneſs.

But by the way, I cannot but take notice of what *Hevelius* ingeniouſly confeſſes, of the great difficulty there is in taking the

the Distance of fixt Stars from the Moon, which is from nothing else but the imperfections of his Common Sights, and all that difficulty vanishes, if the Sights be made another way. Next, He seems to make it a much more difficult business, to take the Distance of the Sun from *Venus*, when she is seen in the day-time; but by a way I shall hereafter shew, it will not only be easie to take the Distance of the Sun in the day-time from *Venus*, but from *Mars*, from *Jupiter*, nay, from several of the fixt Stars.

I shall pass by therefore his *Apparatus*, which seems very great and chargeable, since I shall else-where shew a single, plain way, without any trouble or perplexity, how the matter may be quite otherwise ordered, much to the advantage of the Observator.

As to what he asserts of his extraordinary care, diligence and pains, in dividing and examining the truth of his Instrument, I do no ways doubt it, but that he hath proceeded as far as it was possible for one to do in that way he made use of, but might have saved much of it, if he had thought of the way by Diagonals on Glass, which I have already described. Yet I should have been very glad to have seen the Distances, which he mentions to have taken of eight fixt Stars near the Ecliptick, to wit, *Lucidæ Arietis & Palilicii, Palilicii & Pollucis, Pollucis & Reguli, Reguli & Spicæ, Spicæ & in manu Serpentarii, in manu Serpentarii & Aquilæ, Aquilæ & Marchab, Marchab & Lucidæ Arietis*, and that to so great exactness, as not to miss one single Second in the whole Circle of the Heavens, taken at eight Observations. For to me indeed it seems one of the greatest affirmations I ever met withal, and not less then humanely impossible, were there no Refraction in the Air, and did all the Objects stand still in the Horizon, but the Refraction of the Air, were it much less then it is granted by all, would necessarily cause a variety of a great number of Seconds. And I durst undertake to demonstrate it to any, as plainly as any Geometrical Proposition, that it was wholly impossible for him, with all or any of the Instruments he hath described, to make any one of these Observations, to the certainty of 30 Seconds, whence if that uncertainty be 8 times multiplied, it will follow, he cannot be certain in the whole Circle to 240 Seconds,

Seconds, or 4 Minutes, which how much it is differing from one ſingle Second, any one may judg.

I had many other things to have added, which have occurr'd to me in the peruſing of *Hevelius* his Book, but I will ſay no more at preſent by way of Objection, having, I fear, wearied the Reader, with ſhewing him my doubts and ſcruples, eſpecially about the imperfection of that way of Sights and Diviſions made uſe of by him: Only, to make my Reader ſome mends for his patience, I ſhall deſcribe a ſhort *Apparatus*, which I have contrived for this purpoſe, and in the doing thereof, ſhall be as plain and brief as poſſible the matter will bear.

Since the reading theſe Lectures, the Author having been acquainted, that ſome conſiderable Objections had been made againſt the certainty and accurateneſs of his Inſtruments, and that I had affirmed it impoſſible to perform what he had promiſed in his Book, he returns his Sentiments thereof in a Letter to Mr. *Oldenburg*, to this effect:

——*Cæterum percipio veſtrates non omnes mihi adſtipulari in iſto Dioptrarum negotio, de quibus in machinæ meæ cœleſtis Organographia tractavi, verum etiamſi Cla.* Hookius *& Cla.* Flamſtedius *aliiq; plane aliter ſentiant, experientia tamen quotidiana me edocuit atq; etiamnum docet, rem longe aliter ſe habere in magnis illis organis, quadrantibus ſcilicet ſextantibus & octantibus imprimis quadrantibus Azimuthalibus aliisq; quadrantibus regulis conſtructis, quæ nempe adeo procliviter commoveri & inverti (dum Dioptræ Teleſcopicæ examinantur) imo nullo modo poſſunt, ut quidem Inſtrumenta illa trium quatuorve pedum perpendiculo conſtructa. Rei cum primis in eo conſiſtit, quod nullam plane obſervationem ſuſcipere poſſint ſuis Dioptris Teleſcopicis niſi prius denuo eas examinent ac rectificent; in quo tamen examine variâ viâ, tum jugiter utut ſtudioſiſſime illud ſuſcipiatur hallucinari datur. Adhæc in quadrantibus Azimuthalibus, octantibus & ſextantibus, qua ratione examen iſtud adeo accurate nunquam non haud magno negotio temporiſq; diſpendio inſtitui poſſit, profecto nondum capio, vix mihi perſuadeo ullibi adhuc ullum aliquem magnum quoddam Inſtrumentum 6 vel 9 pedum utpote ſext. octant. vel quadrantem cum regula vel quadrant. Azim. cum pinnacidiis Dioptricis conſtruiſſe, eumq; ad cælum felici aliquo ſucceſſu adhibuiſſe, & quicquam ſolide obſervaſſe; ſi tentaſſet ac per annos aliquot obſervationibus*

vationibus continuo invigilasset sine dubio aliter sentiret. Hoc negotium enim non solum in eo consistit quod stellæ aliquanto distinctius conspiciantur (quanquam fixæ ab eo qui visu pollet & exercitatus est æquè bene nudis oculis discernantur) sed an Instrumenta ab omni parte correcte commonstrent, an pinnacidia Telescopica Instrumentis toties ad quasvis observationes rite imponi & tuto conservari queant; de quibus quidem id omni tempore æquè præcise fieri posse valde dubito. Quare Clarissimos illos viros humanissime rogatos volo nisi jam possideant ejusmodi vastissima organa utpote sext. octant. & quadrant. Azim. Dioptris Telescopicis munita, eaq; cælo continuo admoneant, suspendant judicium paululum, donec longa annorum serie experti fuerint haud fuisse multoties egregie elusos. Nam ex una alterave observatione quadrant. aliquo leviori perpendiculo gaudenti obtentâ, res hæc non est decidenda, sed si quis per 10 & amplius annos assidue observaverint, tum ab ovo seriam stellarum restitutionem per distantias susciperit, poterit quædam certiora in medium hac de re proferre. De reliquo satis mirari nequeo, eas omnes qui ejusmodi Dioptris Telescopicis gaudent, nondum locorum suorum, elevationem poli ubi degunt & observationes peragunt, quantum sciam recte & omnino præcise determinasse & stabilivisse. Hucusq; enim ad aliquot minuta integra Parisiis elevatio poli nondum est definita, alii quippe eandem observationem 48. 49' alii 50'. alii 51', alii 52', alii 53', alii 54', 55' imo ampliorem adhuc statuerunt: sicuti legere est ex dissertatione Petri Petiti de latitudine Lutetiæ, sed nolo in his prolixius esse; ad observationes ipsas provoco, tempus aliquando docebit quorum observationes universas accuratiores fuerint, si modo nonnulli censuram suam eo usq; rejicere possent. Nam video aliquos inter quos etiam Cl. Flamstedius s *invenitur*, prout ex Epistola ad Cassinum apparet, jam judicium de nostris qualibus observationibus tulisse, priusquam illas adhuc viderunt examinarunt vel quicquam de iis cognoverunt. Nolo quidem vanus esse rerum mearum jactator, nec unquam mihi imaginatus sum rem in omni isto negotio circa scilicet restitutionem stellarum fixarum acu omnino tetigisse vel tangere posse. Sed hocce penitus mihi imaginor si totum istud negotium Dioptris Telescopicis suscepissem, quod non solum plurimos annos examinibus trivissem, sed spe sine dubio varia via (de qua hic non est disserendi locus) cecidissem. Exinde gratulor mihi me ad eam sententiam nondum transisse, ac me mea methodo universa perfecisse se quicquid præstitum

præſtitum Dei beneficio erit: an nihil amplius (ut putat Clariſ. Flamſtedius) *quam hactenus & quouſq; progreſſum fuerit, liberum erit cuiq; cum deinde viderit judicium ſuum exponere quinetiam integrum erit alium novum integrum catalogum ſuperadditis tot ac tot centenis nonis fixis, hactenus neglectis alia ratione conſtruere: Verum nondum video an cura hæc moleſtiſſima, tædioſiſſima ac laborioſiſſima, quæ non niſi multorum annorum vigiliis ſuſcipi & peragi poteſt, aliquem adhuc ſerio tangat. Unam aut alteram ſtellam ope Teleſcopii vel Dioptrarum Teleſcopicarum, dum præcipuas ac majores fixas earumq; intercapedines ſupponimus correctas ad debitum locum deducere, tum nonnunquam diſtantias nonnullas ſtellarum capere hæc ludicra ſunt; ſed omnes conjunctim ſecundum longum & latum reſtituere, tum ductu continuo ſingulis ſerenis diebus ac noctibus, tam altitudinum ſolarium quam reliquarum ſtellarum obſervationibus operam dare, easq; orbi exponere ut pateat motuum harmonia atq; Inſtrumentorum certitudo, hoc artis hoc laboris eſt. Quando obſervationes* 20 *vel* 30 *annorum ſpatio continuatas ab utraq; parte aliquando habebimus, nimirum tam quæ Dioptris Teleſcopicis quam quæ ſolummodo noſtris ex cælo deprompta ſunt res omnino clarior erit. Interea quilibet fruatur ſuo ingenio, ac ſua ratione pro libitu rem tentet. Honorificum nobis omnibus erit pro modulo noſtro à Deo conceſſo, rei literariæ incrementum varia via promovere.*

To this Letter of *Hevelius* I have this to anſwer, That the Author neither hath, had, nor can have any experience, to ſhew Teleſcopical Sights not to be as good as the Common, or that they are leſs applicable to large Quadrants, Sextants, Octants, or Azimuth Quadrants, or to any other Quadrants furniſhed with Rules, and ſo fixt, that they cannot be eaſily inverted, or turned, then they are to Quadrants or Inſtruments of 3 or 4 foot Radius. Nor is his Reaſon againſt them of any validity, that no Obſervation can be made, without a repeated previous examination and rectification of the Sights, in which, ſays he, notwithſtanding all the care and diligence, there is a Reaſon of failure and miſtake. For firſt, I ſay, There is leſs need of rectifying the Inſtruments or Sights, after they have been once adjuſted, then of Inſtruments with Common Sights, all things being perfectly fixt, and ſo ſtrong

as not easily to be stirred or removed. I now begin to fear, that he hath not a true notion of the manner of performing the same, otherwise he would never have propounded such an Objection; and indeed he seems to say as much in the following words, *Qua ratione examen illud omni tempore commode & sine magno temporis dispendio institui possit profecto nondum capio.* Though I am very sorry that he should be so: for first, I thought I had about 9 years since, explain'd to him the way, when I exhorted him by all means to the use thereof; at least if he had not understood it thereby, I should, upon his desire, have sent him a more ample and particular Description thereof, or have procured an Instrument of that kind made and fitted for him here. But I fear, he had been some ways or other prepossest or prejudiced against them, before I writ first unto him concerning them, at least before he writ that Answer, which I have before printed in the 5 and 6 Pages, for thereby it appears, that he was then of the same opinion he seems now to continue of. And whereas he thinks, that no tryal hath ever been made of Telescopical Sights, to a large Instrument of 6 or 9 foot, I do assure him, (and I mis-remember, if I did not then acquaint him with as much) that I had then by me several, and particularly one of Sr. *Christopher Wren*'s invention, furnished with two Perspective Sights of 6 foot long each, which I made use of for examining the motions of the Comet, in the year 1665. And if the same thing can be better done with a Quadrant of 6 inches Radius, then he can perform with one of 6 foot the common way, I think he might have concluded at least, that the same thing would be 10 times better done in one of 6 foot Radius, made after the same manner; of this, I am sure, I gave him then an account. Now it is not with these kinds of Instruments, as it is with Common Instruments, where 'tis not possible to make any better then one may be made of 3 foot Radius, because that is capable of Divisions, accurate enough to reach the power of the naked eye; but Instruments with Telescopical Sights, are capable to be made to distinguish minutes, seconds, nay single thirds, if they be proportionably augmented. Nor is there any need that a man must make 7 years tryal of an Instrument, before he can be certain of the greater excellency thereof, for I can be as certain with

with 3 or 4 times viewing an Object through a Teleſcope, and with my naked eye, that I can ſee it better, and diſtinguiſh many more and much ſmaller parts in it through the Teleſcope, then I can with my naked eye, as I could be, ſuppoſing I had been viewing it 20 years together. But yet I muſt aſſure *Hevelius*, my experience hath not depended upon 3 or 4 tryals only; I cannot chooſe but wonder why he ſhould be of that opinion, who hath not been leſs exerciſed in the uſe of the Teleſcope, then any at preſent in *Europe*: Poſſibly indeed his Teleſcopes were not altogether ſo good as now they are made, yet ſure I am, he ſaw more with them then any one can ſee without them, as will ſufficiently appear by his Phaſes of the Moon, *Jupiter* and *Saturn*. But I hope he will not wonder at me, though I do now venture to affirm, without ſtaying 10 years or more to make Obſervations, that I can do more with a Quadrant, Sextant or Octant, of 1 foot Radius, furniſhed with Teleſcopical Sights and Screws, then can poſſibly be done with any other Inſtrument, furniſhed only with Common Sights, though 10, 20, 30, nay threeſcore foot Radius; nor does it at all follow, that the Latitude of *Paris* is not yet exactly known, becauſe Monſieur *Petit* was ignorant of it; but it rather ſhews, that Obſervations made with Common Sights, (ſuch as I ſuppoſe Monſieur *Petit*'s Inſtruments and others, before the publiſhing of his Book were) are no ways capable of certainty to a minute or two.

But I have done, and am ſorry I have been forced to ſay ſo much in vindication of Teleſcopical Sights; and that in the doing thereof, I have been neceſſitated to take notice of the imperfections, that are the inſeparable concomitants of Inſtruments made with Common Sights. Nor ſhould I have publiſhed theſe my thoughts, had I not found them ſo highy decryed by a perſon of ſo great Authority, fearing that thereby other Obſervators might have been deterr'd from making any uſe of them, and ſo the further progreſs of Aſtronomy might have been hindred. Nor would I willingly be thought to depretiate or undervalue the Works and performances of a perſon, ſo highly meriting the thanks of all the learned World, both for his great and liberal expence, and for his vaſt pains, care and diligence, in the performing a Work ſo highly uſefull to

Aſtronomy and Navigation, and of ſuch infinite tedium, trouble, labour and coſt, to the undertaker. I do not in the leaſt doubt, but that it will be a Work worthy ſo excellent a perſon, of perpetual eſteem and fame, and much preferrable to any thing yet done of the like kind in the World, and that he hath gone as far as it was poſſible for humane induſtry to go with Inſtruuments of that kind, and that his Inſtruments were as exact, and compleat, and fit for uſe, as ſuch Inſtruments with Common Sights could be made, and that he hath calculated them with all the skil and care imaginable, and deliver'd them with all the candor and integrity. But yet I would not have the World to look upon theſe as the bound or *non ultra* of humane induſtry, nor be perſwaded from the uſe and improvement of Teleſcopical Sights, nor from contriving other ways of dividing, fixing, managing and uſing Inſtruments for celeſtial Obſervations, then what are here preſcribed by *Hevelius*. For I can aſſure them, that I have my ſelf thought of, and in ſmall modules try'd ſome ſcores of ways, for perfecting Inſtruments for taking of Angles, Diſtances, Altitudes, Levels, and the like, very convenient and manageable, all of which may be uſed at Land, and ſome at Sea, and could deſcribe 2 or 3 hundred ſorts, each of which ſhould be every whit as accurate as the largeſt of *Hevelius* here deſcribed, and ſome of them 40, 50, nay 60 times more accurate, and yet everyone differing one from another in ſome or other circumſtantial and eſſential part. And that this may not ſeem altogether ſo ſtrange, I will aſſure them, that I have contrived above 20 ways for dividing the Inſtrument, each of them as much diſtinct from each other as this of *Hevelius*, and that of Diagonals, and yet every one capable of as great certainty and exactneſs at leaſt, and ſome of them 100 times more. I have above a dozen ſeveral ways of adjuſting the Perpendicularity or Horizontality of Inſtruments, all as exact as the common Perpendicular, and ſome of them very much more, even to what accurateneſs ſhall be deſired, and yet each of theſe very differing one from another. I have as many differing kinds of Sights, for improving, directing, adjuſting and aſcertaining the Sight, ſome of which are applicable to ſome particular uſes, but ſome for all, by means of which that part alſo may

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be improved to what accurateneſs is deſired. I have various ways of fixing thoſe Inſtruments, and appropriating them for this, that, or the other particular uſe. I have various mechanical ways for making and working the ſeveral parts of them with great expedition and certainty, which is a knowledge not leſs uſeful then the knowledge of the theory and uſe of them when made, there being ſo very few to be found in the World that can or will perform it. I have a mechanical way of calculating and performing Arithmetical operations, much quicker and more certainly then can be done by the help of Logarithms, which compleats the whole buſineſs of meaſuring Angles. Theſe I mention, that I may excite the World to enquire a little farther into the improvement of Sciences, and not think that either they or their predeceſſors have attained the utmoſt perfections of any one part of knowledge, and to throw off that lazy and pernitious principle, of being contented to know as much as their Fathers, Grandfathers, or great Grandfathers ever did, and to think they know enough, becauſe they know ſomewhat more then the generality of the World beſides: *Reptat humi quicunq; vult, Cælo reſtat itur, Cælo tentabimus ire.* Let us ſee what the improvement of Inſtruments can produce.

And now to make my Reader ſome amends for his patience, I ſhall give a Specimen or two, of each of the ſeveral parts that belong to the perfecting of celeſtial Inſtruments: And this I ſhall do, in the Deſcription of an Inſtrument for taking all manner of Angles and Diſtances in the Heavens, which if increaſed in bulk, is capable of as great accurateneſs, as the Air or Atmoſphere will ever permit celeſtial Obſervations to be made. Its perfection conſiſts in ſeven ſeveral particulars. 1. In the Sights, which are ſuch as may be made to diſcover the minuteſt part diſcoverable in an Object, they do no ways ſtrain the eye, and are fit for all Sights, whether ſhort-ſighted or old, *&c.* 2. In the Diviſions, which are ſuch as will diſtinguiſh the Angle, as minutely as the Sights will diſtinguiſh the parts or Objects. 3. In the Sights, being ſo contrived, that with one glance of the eye, both the Objects though a Semicircle diſtant, are at once diſtinguiſhed and ſeen together. 4. In the method of ſetting it exactly perpendicular to a Second,

cond, if need be. 5. In its fixation and motion, it being ſo fixed and moved, that if once ſet to the Objects, it continues to move along with them, ſo long as 'tis neceſſary to continue, or be very certain of any Obſervation. 6. In its not being difficult to be made and adjuſted, and its not being without induſtry and deſign put out of order, and its being preſently, and with all imaginable eaſe rectified and again adjuſted. 7. In its not being very chargeable. First, For the Sights, They are no other then plain Teleſcopes, made with two convex Glaſſes, an Object and an Eye-Glaſs, of what length and charge ſhall be thought moſt convenient, fixed into ſquare Boxes or Tubes of Iron or Braſs, and having croſs Clews at the Focus, made with very fine Hair, or ſilk-Worms Clews. One of theſe is fixed upon the ſide of the moveable Bar or Plate of the Quadrant, the Object-Glaſs of which is next the Rim, and the Eye-Glaſs is next the Center. The other of theſe is fixed upon the ſide of the Quadrant by ſeveral Screws, and care is taken to keep it from bending or ſagging. This Tube is made of twice the length of the former, and hath at each end an Object-Glaſs, each of them of the ſame length with the former, and hath two Eye-Glaſſes in the middle, the manner of ordering which I ſhall ſhew by and by under the third head.

But firſt I ſhall explain the manner of fitting a Teleſcope for a Sight. Let a a b b in the 12th. Figure repreſent a Tube, in which let p repreſent the part toward the Object-Glaſs, whoſe Focus is at o, and let n repreſent the Eye-Glaſs, whoſe Focus alſo is at o, let s repreſent the point, where the eye being placed, the whole Eye-Glaſs n will be enlightned and fill'd with the Object, then make a ſmall Tube about an inch in length, and of ſuch bigneſs as it will juſt ſlide within the hollow of the Tube a a b b, and croſs the Cavity of that ſtrain two very fine Hairs or ſilk-Worms Clews, which may croſs each other in the Center of the Cavity, by the means of which Box, the ſaid croſſing Clews or Hairs may be moved to and fro, till they are exactly placed in the very Focus both of the Object-Glaſs and Eye-Glaſs, for if they be not there, the moving of the eye to and fro over the hole at s, will make the Threads ſeem to move upon the Objects, but if they be exact-

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ly in both the aforeſaid Focus's, the moving of the eye will not at all make the ſaid Threads ſeem to move upon the Object, but they will appear as ſteady and fixt to the Object, as if they were ſtrained and faſtned to it. And though they are exceeding ſmall, even as ſmall as the Web of a Spider or Silk-Worm, they will appear very big and diſtinct, and much plainer and bigger then a Thread in the Common Sights, at the further end thereof, will to the naked eye, though above 100, nay 1000 times the bigneſs, which at the firſt glance will ſufficiently diſcover the vaſt advantage theſe kind of Sights have above the Common ones. Nor is this way of Sights at all confined, but may be made to diſtinguiſh the ſmalleſt part of the Object deſirable, even the parts appearing to the naked eye, under the Angle of a ſingle ſecond or third of a Degree, which is ſome hundred of times more curious then the naked eye can diſtinguiſh, without the help of them, for the Teleſcope can be made longer, and the Eye-Glaſs can be made deeper, and according as the Teleſcope is longer, and the Eye-Glaſs deeper, ſo will the Object appear bigger, and more minute parts be diſtinguiſhed, the power of the eye being increaſed proportionably to the length of the Object Glaſs, and the charge of the Eye-Glaſs, and the goodneſs of them both. Now as Sights this way made, are capable of the greateſt accurateneſs deſirable, ſo they are ſo appropriated to the eye, that they no ways ſtrain it, for they may be ſo ordered, as to make all thoſe parts that are to be diſtinguiſhed, to appear to the eye under the Angle of 3 or 4 minutes, which moſt eyes are able well to diſtinguiſh, without uſing too much attention or ſtraining to diſcover them. This is no ſmall convenience, to one that is to make many Obſervations one after another, for the eye by too much attention is apt to be ſuddenly weary'd, and it doth very much harm and weaken the Sight, to endeavour to diſtinguiſh parts ſo ſmall, as appear to the eye under the Angle of a minute, very few eyes being able to reach it at all, and moſt others not without much difficulty and endeavour. 'Tis further conſiderable upon this account, that 'tis fitted for all kinds of Sights: For a ſhort-ſighted perſon, the Eye-Glaſs may be made to ſlide a little nearer the Croſs in the Focus; and for an old or decayed Sight, the Eye-Glaſs may be

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moved a little longer or further off from the ſaid Croſs or Focus; for a dim Eye, the aperture of the Object-Glaſs may be augmented, and the Eye-Glaſs made ſhallower, or of a leſs charge; and for a weak, tender and curious Eye, the charge of the Eye-Glaſs may be augmented, and the aperture of the Object-Glaſs made leſs. And according to the ſeveral conſtitution of the Obſervators eyes, the manner of Sights may be accommodated, which the other Common Sights without the help of Glaſſes, are no ways capable of.

The ſecond thing wherein the perfection of this Inſtrument conſiſts, is the way of making the Diviſions, which I think, is far beyond the Common way, both for the certainty and eaſe of making, and ſecondly, for the plainneſs and certainty of it, in being diſtinguiſhed; nor is it capable of leſs accurateneſs for meaſuring, then the Sights are for diſtinguiſhing. And it excels all the Common ways of Diviſion in theſe particulars: 1. That it is made certain and not by gueſs, we being not at all to depend upon the care, credit and diligence of the Inſtrument-maker, in dividing, graving or numbring his Diviſions, for the ſame Screw makes it from end to end, as you will ſee by and by. 2. That the Diviſions are not at all difficult to be diſtinguiſhed, and there is no uncertainty in the Fabrick, nor can there be any reaſon of miſtake, there being nothing to be looked after, but the Numbers expreſſed in Figures at large, ſufficiently plain to any one that can read the Print of a large Church-Bible. It excels the Common ways thirdly, upon the account of its Compendium; for whereas by *Tycho*'s or *Hevelius*'s way, the Inſtrument muſt be made of 150 foot Radius at leaſt, eaſily and certainly to diſcover and diſtinguiſh Seconds, in this way it may be made to do it within the compaſs of 3 foot Radius. And whereas in either of their ways, even in an Inſtrument of 150 foot Radius, the Diviſions are not eaſily diſtinguiſhed and diſcover'd without the help of Glaſſes, in this way they are made ſo eaſie and plain, that a man cannot miſtake, that is able by his naked eye to diſtinguiſh Decimals of an inch. Now that this is ſo, as I affirm, the Reader will eaſily underſtand, if he conſiders, firſt, that the bigneſs of a minute is hardly half an inch, in an Inſtrument of 150 foot Radins, and conſequently the bigneſs of a ſecond is but $\frac{1}{120}$ of an inch,

inch, which to a good eye is but barely a visible point at the best advantage, and to most eyes is not distinguishable without much difficulty, and to very many not at all without the help of Glasses. Now though *Hevelius* pretends to be able to do much by the help of the new way of *Nonnius*, *Vernier*, or *Hedreus*, yet if he considers what I have now said, he will be of much another mind, a Radius of 10 foot being but a 15th. part of one of 150, and consequently every 120th. part of an inch, being no less then 15 whole Seconds. At least, I am sure, he will be convinced that his own is not true, if he look upon that Specimen of it which he hath printed in his *Machina Cœlestis*, in the Plate T. with a moderately magnifying Glass, as I hinted to him before. He will further understand the truth of my Assertion, if he considers in the next place, that by the help of the Screw, I am able to make the bigness of a Minute as much as I please; for since in an Instrument of 5 foot Radius, a Degree is somewhat better then an inch, 'tis easie enough to understand, that there may be 30 Threads of a Screw in the length of an inch, and consequently there will be but 2 Minutes to fill up the whole Circle of the Index-Plate, and consequently if the Circle be 7 inches Diameter, the Circumference will be almost 22 inches about, and consequently the bigness of a Minute not less then 11, and the bigness of a Second not much less then the 5th. part of an inch. Now the Index-Plate e in the first and 11th. Figures, shews exactly the number of Revolutions, and the Hand 8 in the same Figures, shews the parts of a Revolution, and both these in Characters large and distinct enough; and therefore the certainty and truth of this Assertion cannot be further doubted.

The way then for these Divisions is this: Make a Frame of a Quadrant of hammer'd Iron, after the manner expressed in the first Figure, and in the Center thereof fix or raise a hollow Cylinder, whose hollow may be about a 40th. part of its Radius, and whose convex part may be about a 30th; leave this standing above the Plain of the Quadrant about $\frac{1}{20}$ part of the Radius, let the out-side of this Cylinder be made as exactly round as 'tis possible to be turned or wrought, then make a Ruler or Plate, with a round hole in it at one end, turned, groun'd and fitted exactly about the above-mention'd Cylinder, and as

long as you design the Telescope for the Sights of the Quadrant, this by a Screw on the top thereof must be kept close and steady upon the said Cylinder: Upon the end next the Limb is to be fitted a Socket or Frame with Screws, to carry the Screw-Frame steady and firm, according to the contrivance expreſt in the first and 11 Figures; this Plate must be filed or bended at that part of it which touches the Limb of the Quadrant, so as to lye obliquely to the Plain of the Quadrant, and to be parallel to the Plain of the Frame which carries the Screw, and upon the part beyond the Limb must be fixt with a Screw k, the Frame h h h, which carries the Screw 9 9 9, and the Index-Plate t t; the contrivance of this Frame h h, is to keep the Screw 9 9 9 close against, and very steady to the Limb of the Quadrant, and is moved to and fro upon the Limb of the Quadrant b b b, by the help of the Screw turning upon and against the edge of the Quadrant; and this Screw by reason of its distance from the center and eye, (the reason of the placing of which in that place you will understand by and by) being too far off to be reached by the hand, is turned by a small Rod of Iron, o o o in the first and 11 Figures lying by the side of the Ruler or Plate, which hath a small Wheel q q, at the end next the Limb, by which the Screw is turn'd round with it, and hath a small Handle or Windle p p next the Center, by which it is made convenient to be so turned round. Upon the end of the above-mention'd Screw-Frame h h, is fixed a round Plate t t, which is divided into 1, 2, 3, 4, or 5 hundred equal parts, according as it is in bigness, and as it shall be thought convenient, which Divisions are numbred and marked accordingly, serving to shew what part of a Revolution is made of the aforesaid Screw; for the end of the Screw 9 9 9 coming out through the middle thereof, and a Hand 8 being fastned upon the said end, every turn of the Screw doth make a Revolution of the Index upon the said Plate; and consequently the motion of the arm made by one turn of the Screw, is actually and sensibly divided into 1, 2, 3, 4, or 5 hundred equal parts, which is so exceeding exact, and withal so Mathematically and Mechanically true, that 'tis hardly to be equallized by any other way of proceeding. This Description will be much better understood by

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the Explication of the Figure, and the ſeveral parts thereof.

Let a a a a a, *&c.* repreſent the Frame of the Quadrant, conſiſting of 5 Bars, radiating from the Center, ſteadyed all of them by a Quadrantal Limb, and a ſtraight ſubtending Chord Bar; this whole Frame is to be made of very good Iron, partly welded and partly ſodered together with Braſs; the breadth of the Bars may keep the ſame Proportions expreſs'd in the Figure, and the thickneſs may be about 180 part of the Radius in large Inſtruments. In the Center of this, out of the ſolid Bar, is to be raiſed a Cylinder, as d d, expreſſed above more plainly in the 2d. Figure; the out-ſide of this Cylinder is to be turned and wrought, as Founders do their Stopcocks, as exactly as poſſibly it can be, and the end of the Iron Plate or moveable arm c c c c, ſhaped as is expreſſed in the 3d. and firſt Figure, muſt be bored and wrought upon it very well, ſo as they may turn exactly true, evenly and ſmoothly, without any manner of ſticking or ſhaking, which a good Workman will eaſily perform. This arm being put on the Cylinder, is ſcrewed down faſt by the help of a Screw-Plate, expreſſed in the 4th. and firſt Figures by e e, which hath two notches in it f f, by means whereof a Handle g g in the 6th. Figure, doth readily ſcrew and unſcrew it, as there is occaſion. Between this ſcrew'd Plate and the hole of the Plate c c c c, is a thin Braſs Plate, let on upon an 8 ſided part of the Cylinder, that ſo the turning of the Plate c c c c, may not have any power to unſcrew the Plate e e, which otherwiſe it is very apt to do. Why this Center is thus made, and a hole left in the middle thereof, you will ſhortly underſtand more plainly. Upon the Iron Limb of the Quadrant laſt mention'd, is ſcrew'd and rivetted a Limb of fine Braſs, firſt caſt into that ſhape, and then very well hammer-hardned and filed, repreſented in the Figure by b b b b: This, as I ſaid, by many holes drilled through the Iron and the Braſs, is ſcrewed and rivetted upon the iron Limb, ſo as about half an inch in a Quadrant of 5 foot Radius doth over-hang the iron Limb, and the ends thereof extend a conſiderable deal longer then the Quadrant, the reaſon and uſe of which you will by and by underſtand, when I give the Deſcription of the Screw-Frame.

The edge of this Brass Limb must be, by the help of the Plate c c c c, and a File or Plain, cut very exactly round, to answer the Center of the Quadrant, and the upper side thereof must be plained exactly smooth and flat, upon which Plain-side the Loop-holed Plate c c c c must move, as is visible in the Figure. This Plate at i i must be wrenched or wreithed, so that the Plain thereof must stand parallel to the Plain of the Iudex-Frame, and by the wreithing of it at i i, as aforesaid, there is room left for the Screw to lye obliquely, without the Screws touching the aforesaid Plate, or grating against it. The reason why I put the Screw obliquely to the Plain of the Quadrant is, that that part of the Thread which toucheth the edge of the Limb, may be exactly at right Angles, or perpendicular to that Plain, and consequently that the Teeth upon the said edge, may likewise be exactly cross or perpendicular also, and consequently that no bending of the Rule c c c c, (to the end of which the Frame of the Screw is fastned) may at all vary the Angle, nor any unequal thickness in the Limb of the Quadrant, but that the turning only of the Screw shall produce a variation, and that exactly proportionate to the number of Revolutions, and the parts thereof, shew'd by the Index.

The way to know exactly what the obliquity of the Screw ought to be, to make the Teeth upon the Limb perpendicular, is to number how many Threads of the Screw there are in a known length, and what the Compass of the said Screw, or the Cylinder out of which it is made is, and multiplying the said Compass by the number of Revolutions into a Product, the Proportions of that Product to the known length, will give the obliquity of the Screw, the Product being the Radius, and the known length the Tangent of obliquity, thus; Suppose in the length of 4 inches, there be 83 Threads of the Screw, and that the Compass of the Cylinder of the Screw be $\frac{92}{100}$ Centesms of an inch, I multiply the $\frac{92}{100}$ by 83, the number of Revolutions, and it giveth me 76$\frac{36}{100}$, that is 76 inches, and 36 Centesms of an inch, making this Product the Radius, and the known length, *viz.* 4 inches, the Tangent of the obliquity of the Thread of the Screw to the Axis thereof, or of the Axis of the Screw to the Plain of the Quadrant. The demonstration

monſtration of this is ſo plain, that I need not inſiſt upon it, for the length of the Thread of the Screw is the Secant, the Compaſs of the Cylinder is the Radius, and the bigneſs of the Thread, or the Diſtance between two Threads, is the Tangent, in a right angled Triangle, and the Screw is ſuch a right angled Triangle, wound about a Cylinder, putting the Tangent thereof parallel to the Axis of the Cylinder, and conſequently in the Mechanical tryal of theſe Proportions, the more Threads are taken to make that compariſon or meaſurement, the more exact is the inclination found. The conſideration of which doth plainly ſhew, how exact a way of Diviſion this by the help of the Screw is, for the whole Quadrant is thereby reſolved into one grand Diagonal, the ſame with the Triangle, the length of the Thread upon the Compaſs of the Cylinder being the Diagonal, and the Diſtance of the two ends of thoſe Threads, in a Line parallel to the Axis, being the ſpace to be divided by it, and conſequently by augmenting the bigneſs or Compaſs of the Cylinder, and diminiſhing the Thread, you may augment the Diagonal in any Proportion aſſigned. Or by making the Hand or Index upon the end thereof, of double, treble, quadruple, decuple, *&c.* of the ſemi-Diameter of the Cylinder, out of which the Screw is made, you may duplicate, triplicate, quadruplicate, decuplicate, *&c.* the ſaid length of the Diagonal, in Proportion to the ſpace to be divided.

The next thing then to be deſcribed is the Screw-Frame, made of Iron, much of the ſhape repreſented by h h h, in the firſt and 11 Figures: This Frame, by the help of a Screw through the aforeſaid Plate, whoſe head is expreſſed by the round head k, is fixed on to the long Plate from the center, and by the help of the Screw l, is forced and kept down very cloſe, upon the edge of the Limb of the Quadrant; the Frame hath 4 Collers for the Screw-Pin to run againſt, which are indeed but half Collers, ſerving only to keep the Screw ſteady; two of theſe are made with moſt care, marked with m m, in the 11th. Figure againſt m i, doth reſt the Shoulder of the Screw-Pin 3, which is kept cloſe home againſt it, by the Cylinder g g, in the 10 and 11 Figures; the ſharp Conical Point of this Screw 9 9, goeth into the Conical hole, at the

end of the ſaid Cylinder g g g. The ſhape of this Cylinder, and the Screw by which it is forced againſt the end of the Screw 99, is repreſented in the 10th. Figure; 7 in the 9th Figure repreſents the Conical Point; 3 the place lying againſt the Coller m i; 6 the Screw that moves upon the edge of the Limb of the Quadrant; 5 the Nut or Pinnion by which the Screw is turn'd by a Rod from the Center, expreſt alone in the 8th. Figure, but the manner how it lyes in the Frame, is expreſt by p p o o o in Fig. 1. o o o repreſenting the Rod; p p the Handle by which it is turned; q q the Nut or Pinnion that turneth the Pinnion 5 of the Screw; s r the Collers or Holes that hold it faſt to the moveable Plate or arm of the Quadrant; s s repreſenteth two ſmall pieces that clip the edge of the Limb, and ſerve to keep the Screw-Frame ſteady and true in its oblique poſture, and move equally on the Limb, by a ſtrong ſpringing of one ſide of it; t t repreſenteth the Index-Plate, which is divided into what number of parts are thought neceſſary, 1, 2, 3, 4, or 5 hundred parts, according to the bigneſs of the Thread of the Screw at 6, a greater Thread requiring a more minute Diviſion, and a ſmaller Thread requiring a more groſs. Theſe Diviſions are pointed at by the Index 8 at the end of the Screw, and the number of Revolutions or Threads are marked on the Limb of the Quadrant, and pointed at by the Tongue e e, upon the which is faſtned a ſmall Pin f, ſerving to carry a Lens over the Point of the Tongue, which maketh the number of Threads appear more plain and big: The manner of doing which upon the Frame of the Screw, is ſo eaſie, that I ſhall not ſpend more time in the Explication thereof, and the manner of making the whole Inſtrument, will be eaſie enough to any ingenious Workman; but if any perſon deſire one of them to be made, without troubling himſelf to direct and overſee a Workman, he may imploy Mr. *Tompion*, a Watchmaker in *Water*-Lane near *Fleetſtreet*; this perſon I recommend, as having imploy'd him to make that which I have, whereby he hath ſeen and experienced the Difficulties that do occur therein, and finding him to be very careful and curious to obſerve and follow Directions, and to compleat and perfect his Work, ſo as to make it accurate and fit for uſe,

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By the help of these Indices, 'twill be easie and plain to see how many Revolutions of the Screw, and what parts of a Revolution make a Quadrant of a Circle, and consequently 'twill be easie to make a small Table, which shall shew what parts of a Quadrant, divided into Degrees, Minutes and Seconds, will be designed by the Revolutions, and parts of the Revolutions of the Screw. As for instance, If I find that 1600 Revolutions and 912 make a Quadrant, then 17|788 Revolutions make a Degree, and 296 Millesms of a Revolution make a Minute, and about 5 Millesms make a Second, thence 'twill be easie to find (if you observe) an Angle to contain 294|358, that is, 294 Revolutions, and 358 Millesms of a Revolution, that the Content of that Angle in Degrees, Minutes and Seconds, is 16 Degrees, 32 Minutes, and 47 Seconds, which is plain enough, and much less subject to mistake, then the common way made use of. I shall therefore proceed to

The third particular, wherein this Instrument excels all others, and that, is, That one Observator with a single glance of his eye, at the same moment doth distinctly see, that both the Sights of the Instrument are exactly directed to the desired Points of the two Objects, and this, though they be removed by never so great an Angle, nay, though they are opposite to each other directly in a Line. This, I question not, will by all that know any thing of Instruments, or celestial Observations, be accounted one of the greatest helps to such Observations, that was ever found out. For whereas other Instruments require two Observators, for taking a Distance in the Heavens, and *Tycho* generally made use of four, amongst which there was necessary so unanimous a concurrence in their readiness and certainty, that the failure of any one spoyl'd all the rest, and made the Observation become uncertain and of no use; and such Instruments as were contrived for one Observator, were accompany'd with so great difficulty, in the adjusting to both the Objects, being both in a continual and swift motion, and but one to be seen at once, that they were generally left off and dis-used, there being so vast a trouble and fatigue of looking now upon one, then upon another, by many repeated tryals, and so many new settings of the Instrument to the Objects in motion, before the Sights could be adjusted, besides the great-

great uncertainty at the beſt, of ſeveral Minutes of the truth In this way, the Obſervator has no farther trouble, then firſt, to ſet the Plain of the Quadrant in the Plain of the Objects, and by the Screw to move the arm of his Inſtrument, till he perceive both the Objects to touch each other, in thoſe Points he would meaſure the Diſtance between. That this is ſo, he will eaſily perceive, when he underſtands the method of ſo adapting two Teleſcopes, that by looking in at one ſmall hole in the ſide of one of them, he will be able to ſee both thoſe Objects diſtinctly to which they are directed, how much ſoever ſeparated. The way then of doing it is in ſhort this.

Joyn them together at one end, by a hollow Joynt that has a hole through it, about $\frac{1}{4}$ of the hollow of the Tubes, prepare two ſquare Tubes of Wood, Braſs, Iron, *&c.* of what length you pleaſe, and directly againſt the Center of this hole in the Joynt, make a ſmall hole, about the bigneſs of the blackeſt part or pupil of the eye, ſo as the eye looking in at that hole, may ſee perpendicularly into the lower Tube, then obliquely place two pieces of reflecting Metal, very well and truely poliſht, ſo as to reflect the Axis of both thoſe Tubes, perpendicular or at right Angles, which is by fixing the Plain of the Plates, inclined to the ſaid Axis, in an Angle of 45 Degrees, let the upper reflex Plate reach from the upper ſide of the Tube, ſo low as to touch the Axis or middle of the Tube, and let the lower extend over the whole Tube, from the top to the bottom, and from one ſide to the other. Theſe will be known to be duely placed, if looking in at the ſmall hole againſt the Center of the Joynt, the two round holes of the Tube do appear to the eye to coalleſce into one, and that the eye ſees directly through the lengths of them both alike. Then into theſe Tubes fit two Teleſcopes, with convex Eye-Glaſſes, and croſs Threads for Sights in their Foci, that they may be both of them at due diſtance from the eye, looking in at the ſide-hole, then opening thoſe Tubes upon the ſaid Joynt to any Angle, and looking in at the ſide hole, you ſhall plainly diſtinguiſh at once both the Objects, that are brought into the Tubes directly, and reflected up to the eye.

That this may be the plainer underſtood, I ſhall add a Delineation thereof *in plano*.

Let

Let a a b b in the 12th. Figure represent the upper Tube, and c c c c the lower Tube, and let d d represent that part of the Joynt, which belongs to the lower Tube, at one end, by which they are joyn'd together, and can be open'd in the manner of a Sector. Let i represent the hollow or center of this Joynt, which communicates the Cavities of the two Tubes. Let e e represent that part of the said Joynt which belongs to the upper Tube, being only a hole through the lower side, big enough to incompass the Cylinder d d of the lower Tube; and let r r represent a Plate screw'd or pinn'd on, to keep the parts of the Joynt together instead of rivetting. Let s represent the hole in the side, by which the Eye h is to look in, and f the reflex Mettal in the upper Tube, reaching only half way the Tube, and g g the reflex Mettal in the under Tube, reaching over the whole Cavity; then will n o and p represent the Eye-Glass, Sight-Threads, and Object-Glass of the upper Tube, and k l and m the same parts in the lower, and whatever Angle the Tubes make to each other, whilst they open upon the before-mention'd Joynt, the Eye h looking in at s, will see directly by the Axis of them both, and see the Sight-Threads distinctly crossing the Points of the Objects, whose Distances are to be measured.

These being thus explain'd, I suppose, it will be no difficult matter for any man to conceive, how these may be apply'd to the above-described Quadrant; for 'tis but supposing c c, the upper side of the under Tube in this Figure, to represent a p a p, the fixt side arm of the Quadrant, and d d the Joynt of this, to represent d d the Joynt of the Quadrant, and b b the under side of the upper Tube, to represent c c c the moveable arm of the Quadrant, and applying two Tubes to these parts, and fitting them with reflecting Plates, Eye-Glasses, Sight-Threads, and Object-Glasses, at due Distances, the whole will be performed.

These Tubes thus fitted, will serve to take any Angle less then a Quadrant, to what exactness i desired, but for bigger Angles, the Contrivance must be somewhat varied, the Description of which I shall now add.

Let either of the two Tubes for the Sights, be made of double the length of the other, that is, let it be as long behind the

Center as before it, and make the Reflex-Glass, that it may be turned round, and reflect the Ray exactly backwards, as before it did forward, then fix into this other half of the Tube a Telescope-Sight, in all things fitted, adjusted, and like the other two, then adjust them, that they may look forwards and backwards in the same like, which being done, the Reader will easily understand how any Angle may be taken, even to the extent of two right ones: For 'tis plain enough, that the two Tubes I first described, apply'd to the Quadrant, will measure any Angle to a Quadrant or right Angle; and 'twill be as easie to understand, how by the help of the Reverse-Tube, any Angle between a Quadrant and two right Angles may be measured.

To make this a little plainer to the Reader, let c c c c c in the 12th. Figure represent the under Tube or fixed Sight, s the hole or Eye-cell, t r a round piece carrying the reflex Mettal g g; this is made to turn round, and the reflecting Metal g g being fixed to it within the Tube, is carried round also with it. Let s i k l m x represent the Ray passing forwards by the Eye-Glass, Thread-Sight, and Object-Glass; then this round piece t r being turned and made r t, as in the 13th. Figure, is represented, and with it the reflecting Mettal g g, here marked q q, being turned also: the Line s q k l m y will represent the Ray reflected, and passing backwards by the reflex-Metal q q, Eye-Glass k, Thread-Sight l, and Object-Glass y.

The measure of the Angle is found by the same Apparatus or Screw-Plate; for as much as the Screw-Plate would shew the Angle less then a Quadrant, if the fore-part of the Tube were used, by so much is the Angle more then a Quadrant, if the reverse or back-part of the Tube be used; and the same reason of the accurateness and certainty for the one, is good for the other, without being lyable to any manner of Objection or Inconvenience.

It remains therefore now only to shew, First, How these two Perspective or Telescope Sights, placed within the same Tube, may be made to look exactly forwards or backwards in the same Line. And secondly, How they shall be adjusted to the Telescope, fixt upon the moveable arm of the Quadrant,

ſo as to know when the Diviſion-Angle begins, and when they are open'd to a Quadrant, right Angle, or 90 Degrees; for unleſs theſe be aſcertain'd, and fixt to as great a meaſure of accurateneſs, as the contrivance of the Screw is capable of dividing, or the Teleſcope-Sights are capable of diſtinguiſhing, or the Perpendicularity aſcertain'd, all the pains, care, induſtry, and curioſity, beſtow'd about the other, are of no uſe.

Firſt then, For fixing the Thread-Sights of the two Teleſcopes within the ſame Tube, ſo as to look directly forward and backwards, care muſt be taken, that every one of the four Glaſſes, that is to ſay, the two Object-Glaſſes, and the two Eye-Glaſſes, muſt be ſo ſteadily and ſecurely fixt into the Tube, that they cannot by any means be ſtirr'd or removed; the manner of doing which, I ſuppoſe, ſo exceeding eaſie, that I need not ſpend time in deſcribing a way to do it. Next, Sufficient care muſt be taken of the ſtiffneſs of the Tubes, that they may not warp or bend. Thirdly, One of the Thread-Sights muſt be fixt as firmly and ſecurely as the Glaſſes, and ſo, that the croſſing of the Threads may be, as near as poſſible, in the Axis of the Object and Eye-Glaſs, the other Thread-Sight muſt be left free, till by ſeveral tryals it be found to ſtand exactly in the ſame Line with the firſt; the manner of doing which, I ſhall now deſcribe.

There being two Threads which croſs each other, the one Perpendicular and the other Horizontal, care muſt be taken, that both theſe lye exactly in the ſame Lines with the Horizontal and Perpendicular Threads in the other Sights; and in order thereunto, there muſt be two Frames of Braſs, repreſented in the 29 and 30 Figures of the 2d. Plate, of the bigneſs of the hollow of the Tube; theſe muſt have groves made in the Tube fit to receive them, in which they may by the help of Screws be moved, and made to ſlide to and fro, as there is occaſion, for their adjuſting. Next, They muſt lye ſo cloſe together, that the Hairs may touch each other. And thirdly, They muſt croſs exactly in the Focus of the Object and Eye-Glaſs. One of theſe Frames muſt carry the Perpendicular Thread, and by a Screw in the ſide of the Tube, muſt be moveable to the right or left ſide, as there is occaſion; the other

Frame must carry the Horizontal Thread, and by a Screw in the top of the Tube, must be made to rise or fall in the Tube, as there is need. The Mechanical Fabrick of which is so easie, that, I hope, I need not spend time in the further Description thereof, but refer the Reader to the 29 and 30 Figures.

These things being thus done, from the top of some Turret, or any other Station, where two opposite places at a considerable distance, as half a mile, or a mile or two, can be plainly seen, find out two Points, which, at the first looking through your Glasses, you find to be shewn out by the Crosses of the Thread-Sights, then note those Points very diligently, that you may be sure to find them and know them again, when you have removed the Glasses; this done, turn the ends of the Tube, and (if you were looking Eastwards and Westwards) turn that part towards the East which before looked Westwards, and *vice versâ*, and find out the two Points you saw in the former Observation, then directing that part that hath the fixt Threads, to the Point that was seen before by the moveable Threads, find out the other Point, which you will be sure to see within the compass of your Eye-Glass, and observe how far the cross Threads are now removed from it, either Northwards or Southwards, upwards or downwards, then, as near as you can, by your judgement half that Difference, and by the Screws move the Frames, that the Threads may stand in the middle between the two Points, then take notice again of the Points shewn by the Threads, and turn the Tube again: Do this so many times, till you find upon converting the Tubes, that you see the same Points to be marked by the Crosses of the Thread-Sights, with which end soever you look on them, and then the Tube will be exact and fit for use.

The reason of this adjusting will be sufficiently plain, to any one that shall consider the 14th. Figure; Where let y represent the middle of the Tube t u b, or the place of the Eye, and let w represent the Object seen Westwards, and e the Object Eastwards, at the first view; then keeping the middle of the Tube exactly upon the same Point u, turn the end of the Tube t towards the East, and the end b towards the West, and find out first the Eastern Object e, and finding the

other

other Croſs to direct now to the Point p, and not to w, divide the Diſtance between the Point w, and the Point p, as exactly as you can, in half, which if you chance to hit exactly at firſt, it will be the middle Point m, but if you do not, but you rectifie it only to r, then by the next turning of your Tube you will find s, where you muſt again rectifie to half the Difference between s and r; now the Difference being grown yet leſs, you will a 3d. or 4th. time ſet it ſo exactly, as to ſee the Points m and e, which lye in the ſtraight Line with the Center of the double Tube.

The 4th. thing wherein this Quadrant exceeds the Common, is for its accurateneſs for taking Altitudes; and this is done by the help of a Water-Level, for adjuſting the exact Perpendicularity thereof. This Level may be made and fixed ſo exactly, that any Obſervator may be ſure of the Level of his Inſtrument to a Second or two. The Level it ſelf is nothing but a ſhort Tube of Glaſs, about 6 or 8 inches long, Hermetically ſealed at each end, and filled with a Liquor that will not freeze nor grow foul with ſtanding.

The Glaſs, as near as can be gotten, ſhould be Cylindrical and ſtraight, it being the better the nearer it be to a ſtraight, provided it have a ſenſible bending or ſwelling in the middle, the gibbous part of which ſhould be ſet upwards, and a proper Cell and Box made for it of Braſs.

This Glaſs is to be filled almoſt full of diſtill'd Water, to which about a 3d. part of good Aqua-fortis or ſpirit of Niter hath been put, to keep the ſame from freezing, and alſo from growing foul, then carefully ſealed up Hermetically, and placed in its Box of Braſs, and with hard Cement fixed into the ſame, which by Screws is fixed to that ſide of the Quadrant, that is to lye Horizontal.

The Braſs Box being thus fixed to the right ſide of the long fixt Tube ap ap ap, and underneath the Quadrant, ſo as not to hinder the free movement of the arm c c c, as at x x; the next thing to be done, is by it to ſet the Quadrant truly Horizontal, which is thus performed.

Setting the ſide a p a p a p Horizontal, and the Limb of the Quadrant upwards, and looking in at the Center, take notice of two Objects in the Horizon oppoſite to each other,

obſerve

obſerve the limits of the bubble of Air on the top of the Liquor, on each ſide of the middle of the Level, and make a mark, then turning the ends of the Quadrant, ſet it, till the ends of the bubble ſtand as in the former Obſervation; then look again at thoſe Objects in the Horizon, and find what the difference is between theſe oppoſite Objects, and thoſe in the former Obſervation; then halve the difference between them as near as you can, and by your eye ſet the Sights to the middle between them, by inclining the Quadrant, then by the Screw that rectifies the Level, ſet the Glaſs-Level ſo, that the ends of the bubble may be equally diſtant from the middle, and convert the Quadrant again, and ſee if the ends of the bubble ſtanding at the ſame marks, the two oppoſite Teleſcope-Sights do ſee the ſame Objects, for if ſo, you are aſſured of the perfect Horizontality of the Sights, upon the fixt arm of a p a p; but if you do not find it ſo direct to the ſame Objects, continue examining and converting, till you find it perfect.

Now this way of Perpendicular being ſubject to the inconvenience of heat and cold, which doth rarifie and condenſe the Liquor, and conſequently make the bubble of Air leſs or more, care muſt be taken, to mark all the varieties of thoſe kinds of the bubble, that are cauſed by the degrees of heat and cold, which you may thus eaſily effect.

Reduce the Liquor in the Tube of the 24th. Figure, by the help of Ice and Salt, to as great a degree of cold as you can, then by the method newly directed, ſet the Quadrant Horizontal, and mark the two ends of the bubble with 44, then by gently applying heat to the ambient Air, warm likewiſe the Water, and obſerve the expanſion thereof at both its ends, and mark them on the Glaſs with the point of a Diamant, as 33. 22. 11. 0 0, which being done, it will be exceeding eaſie at any time, to adjuſt the Quadrant to any accurateneſs deſired, by being careful to ſee, that the two ends of the bubble be proportionably extended, as to 0 0, 11, 22, 33, 44, &c. or to any intermediate ſpace.

The Contrivance of faſtening and adjuſting this Level to the Quadrant or other Inſtrument, will be very eaſily underſtood, by the Delineation thereof in the 24th Figure.

Let

Let a a a a repreſent the Frame or Plate of Braſs, which by four Screws d d d d, is fixed to the Tube, as before. This Plate hath 4 upright Cheeks, b b, c c, between which the Braſs Box e e e e, (into which the Cylindrical Glaſs-Level f f, is fixed with hard Cement) is held ſteady, without any manner of ſhaking. This Braſs Box, at the end of it near the right hand, hath 2 Pevots, which are fitted exactly into 2 ſmall holes in the Cheeks c c, and at the other end next the left hand, hath a ſmall Screw-Pin g, which holds it down faſt to the bottom Plate, and keeps it from riſing out from between the Cheeks b b, which a very ſtrong Spring lying underneath it, between the Plate a a, and the Box e e, would otherwiſe force it to do. By this Screw the Level is to be adjuſted to the Sights of the Quadrant, by the way I juſt now deſcribed, and being once thus adjuſted and fixed, 'tis not eaſily put out of order, without moving or altering the Screw g, which may eaſily be prevented by 100 Contrivances.

The Reaſon of the accurateneſs of this kind of Level, will be eaſily diſcover'd, if we conſider, that the upper part of the Tube being very near to a ſtraight Line, is conſequently either a part of a Circle of a very great Radius, or of ſome irregular Curve, very near of the ſame nature with a Circle, as to this buſineſs of Levelling, and conſequently a Degree of the ſame will be proportionably large, and the flexure of the Tube may be made of a Curve of ſo large a Radius, that every Second of Inclination may cauſe a change in the Level of a very ſenſible length.

This can hardly be performed by the ordinary way of Plumbets, without hanging from a vaſt height, which is not practicably to be performed, without almoſt infinite trouble, expence and difficulty, and when done, can be of no uſe in the World, as any one will grant, that conſiders the vaſt Apparatus that is requiſite to obviate the great unſteadineſs of Buildings, the motion of the Air, and a multitude of other incumbrances.

Now the Curvature this way made may be a portion of a Sphere of 1000 foot Radius, or more, if it be deſired, and conſequently a Minute of the ſame will not be leſs then $\frac{20}{100}$ of a foot, and every Second will be almoſt half a Centeſm of a foot,

foot, which is sufficiently distinguishable to the naked eye. So if the Glass Cylinder be 9 inches long, it may contain two whole Minutes of such a Circle between f and f, and one between 4 and 4, and consequently the said Glass may be set Horizontal to the certainty of a Second, which is hardly to be ascertain'd any other way.

But there remains yet one great Difficulty, how to be able to make such a Curviture, for though the thing be true in theory, yet is it not without some trouble, put in practice. Very few Glass Canes are so conveniently bent, as is desirable, and 'tis as difficult to find them true straight.

To prevent this, If Glass Canes be used, there must be much care taken, and many tryals made, for the finding what pieces, and what side of those pieces will be most fit for this purpose, for our Glass-House Workmen know not yet a way, certainly to draw them of this or that curviture or straightness, nor are they easily ground into a straightness or curviture by the Glass-grinder afterwards, though that can be done with some trouble. But diligence and tryal will quickly find some piece or other, that will be sufficiently exact for any tryal, among those which are only drawn at the Glass-House. I made use of one of another form, such as is described in the 25th. Figure, which I found to do exceeding well, the dark part representing the Water, and the lighter part the Air. This was made of two Glasses, drawn in distinct Pipes at the Glass-House, but joyn'd together in the Lamp, and the upper part of the larger or under Tube, was incurvated with its convexity downwards, so that the Water touched the middle part, and the bubbles of Air at each end thereof, communicated together by the small Pipe above. I tryed also another way, by which I was more certain of the truth of the Curvity, and could make the Curvity of a greater Circle: This was by a long piece of a Looking-Glass-Plate, ground very smooth and polished, which by the help of Screws I bent upon the circular edges of a brass prismatical Box, and cemented the same very tight, with hard and soft Cement; this Plate had a hollow Channel ground in it the length thereof, which serv'd to keep the bubble in the middle. By this means, 'tis not difficult to bend such a Plate, into the Curviture of a Circle of 50,

60,

60, 100, 1000 foot Radius, and the Braſs Box can eaſily be made to fill or empty, as there ſhall be occaſion for the uſe thereof, ſo that the Bubble may be at any time left, of what bigneſs ſhall be deſired. It will be convenient alſo to varniſh the in-ſide of this Braſs Box with Lacker-Varniſh, very thick and cloſe, both to keep it from ruſting, and alſo to preſerve it from being corroded by Aqua-fortis, whenſoever there ſhall be occaſion to put it in, for the cleanſing the inward tarniſh and foulneſs of the Glaſs-Plate. This Curvity of the upper ſide of the Level may be made, by grinding the under ſide of ſuch a long Plate of Looking Glaſs, upon a Convex Glaſs-Tool of 50, 60, 100, 1000 foot Radius, and poliſhing the ſame accordingly of that Figure: The Curvity of the ſaid Plate is expreſs'd in the 26th. Figure. Now what by this way may be done with Water and Bubbles of Air, the ſame may be done with the ſame Glaſſes turned upſide-down, by the help of an exactly round and poliſht Cylinder or Globule of Glaſs, Chryſtal, Cornelian, Agate, or other exceedingly hard and cloſe Stone, after the manner repreſented in the 27th. Figure, for the Ball or Cylinder will naturally roll to the loweſt part of the Concavity, and there ſtand. But in the doing of this, great care muſt be taken, that the Globule be exactly round and poliſht, and that the Concavity of the Plate be as ſmooth and well poliſht, and that they be both very clean and free from duſt, otherwiſe the Cylinder or Globule will be apt to ſtand in a place where it ſhould not, and conſequently produce conſiderable errors.

And here I cannot omit to take notice of a very curious Level, invented by Sr. *Chr. Wren*, for the taking the Horizon every way in a Circle. Which is done by a large Concave, ground and poliſht on a very large Sphere, and the Limb of it ground and poliſht on a flat, for by placing the ſame Horizontal, and rectifying it by a ſmall quantity of Quick-ſilver, poured into the Concavity thereof, 'twill be eaſie, by looking by the flat poliſht Limb, to diſcover the true Horizon. The only inconvenience I find in it is, that the ☿ hath ſome kind of ſticking to the Glaſs, but a ſmall Chryſtal Bowl, I ſuppoſe, may remedy that inconvenience, and make it fit for uſe.

The 5th. thing wherein this Inſtrument is made to excell

others, is in its easinesses to be adjusted to the Objects, and in this, that being once adjusted, the whole Instrument is so order'd, as that it will remain constant to those Objects, though they are moved. The want of this is so great an inconvenience, in all other Instruments hitherto made use of, that almost all Observations have been thereby vitiated. And *Hevelius*, to prevent and obviate this, hath found out many Contrivances, but they are such, as though they do it in part, yet 'tis but in part, and that with much trouble and inconvenience. I need not spend time to shew, how many inconveniences his way by 4 several Hand-Screws, to be managed by 2 Observators at the least, is subject to; they are indeed so many and so great, that it was not without very good reason, that he so often appeals to experience, for the truth is, there was great need of long practice and much experience, to be able to make an Observation in that way well, the removal of every one of those Screws, having an influence upon every one of the other, so as no Screw could be turn'd, but the whole Instrument was put out of its due situation, and both the Objects being continually in motion, the whole Instrument was to be rectifi'd every moment. There was therefore necessary so great a judgement and dexterity, to manage every one of those Screws, that without an acquired habitude and handiness by long practice and experience, nothing could be done to any certainty, nay, not even to that little accurateness that the common Sights are able to reach. But this, though it were a very great unhappiness to *Hevelius*, that he was not furnished with better Contrivances, yet it no ways tends to his dispraise, for his most extraordinary and indefatigable care, pains and industry, is so much the more to be admired, esteem'd and honour'd, and will be so much the more, by such as have by experience found the difficulty, of making any one Observation certain in that way.

But that he or any other, that hath a mind to make further Tryals and Observations, may be freed from this intollerable trouble and difficulty, I have thought of this following Instrument, by means whereof the Quadrant being once adjusted, and set to the Objects, will continue to be so, for as long a time as shall be desired, without at all requiring the help of any one hand of the Observator, though he be but one.

My

My way then in ſhort is this: I make an Axis of very dry and ſtrong Dram-Fir, of a bigneſs thick enough for its length, to defend it from bending; at the lower end of this, I fix into the middle of it, (well bound and hoop'd about with Iron) a Center or Point of Steel, very well turn'd, hardned and ſharp, which is to move in a conical hole fit to receive it, of as good and well hardned Steel; at the other end of this Rod, I fix another piece of Steel into the middle thereof, that, immediately contiguous to the Wood, hath a Neck very well turn'd and hardned, a little tapering from the Wood outward, which is to be moved in a Collar fit for it, as I ſhall ſhew by and by; and at a convenient Diſtance from the ſaid Neck, as at ſomewhat more then half the Radius of the Inſtrument, is made a Cylindrical Neck, fitted with a Collar of Braſs, with a Joynt, and other Apparatus, large enough to carry the Table and Inſtrument firm and true, without ſliding or yielding in its Socket, after it be once ſet. This Axis by the Collar and conical hole below, I place parallel to the Axis, which by ſome tryals is eaſily enough adjuſted; about the Cylindrical Neck, at the upper end of this Axis, is a Socket of Braſs faſtned with a Screw, which Socket claſpeth in a Joynt, a ſhort Arm, which hath at one end a Ball that is fitted into a Socket, that is fixed under the Table and Frame of the Quadrant, and at the other end a Counterpoiſe of Lead, to ballance the weight of the whole Apparatus, about the Quadrant, upon the middle Line of the long Axis, then the Table and Quadrant is rectifi'd, ſo as to lye in the Plain of the two celeſtial Objects, whether Planets or fixt Stars, and by the ſmall Screws in the Sockets it is fixt in that Plain. What further adjuſting is requiſite, is done by the help of ſmall Screws in the Quadrant it ſelf, which are eaſily enough conceiv'd without Deſcription. The Table being adjuſted to the Plain of the Objects, with the Quadrant on it, and all counterpois'd pretty near by the poiſes underneath the Table, and the fixed Sight directed to one of the ſaid Objects, the ſaid Table and Inſtrument continues to be in that Plain, ſo long as is deſired, without any farther trouble to the Obſerver, though the Objects continually change their places, and the fixt Sight remains directed at one of the Objects, till the other can be found by the moveable Sight. To effect which

motion of the Table and Instrument, a Watch-work is fitted to the Axis, so as to make it move round in the same time, with a diurnal revolution of the Earth, and consequently to keep even pace with the seeming motion of the fixt Stars; the manner of doing which is thus: About some part of the Axis, where 'tis most convenient for the Room in which 'tis to be used, fix an Octant of a Wheel of 3 foot Radius, let the Rim of this be turn'd true to the Centers of the Axis, and cut the edge thereof into 360 Teeth, there being so many half minutes of an hour in the 8th. part of a whole Revolution, though these minutes and hours which respect the fixt Stars, will be considerably shorter then the solar hours; then fit a Worm or Screw to these Teeth, that one revolution of the Worm being made in ½, a minute may move one Tooth forward; the revolution of the Worm is adjusted by a circular Pendulum, which is carried round by a Flie, moved in the form of a one wheel'd Jack, from a swash toothed Wheel, fastned upon the shank of the Worm or Screw above-mention'd; the weight that carries round this Wheel must hang upon the shank of the Worm, and must be of about a 3d. or 4th. part of the weight of the Quadrant and Table, that it may carry it round steadily and strongly; and the circular Pendulum must be so order'd, that the Observator may at any time of his Observation either shorten or produce the length thereof, so as to make it move quicker or slower, as there shall be occasion, which is done, by sliding the hole upon which the Pendulum makes its conical motion, a little higher or lower, without lifting up or letting down the Pendulum, or else by winding up the Thread of the Pendulum a little shorter, or letting it down a little longer, by the help of a Cylinder, above the hole or apex of the Cone, in which the Pendulum is moved.

This whole Contrivance will be somewhat better understood by a Delineation. Let a b then in the 15th. Figure represent the Axis of Fir or Iron, c the conical Point at the bottom, d the conical center or hole in which it is to move, e the Collar above, in which the tapering Neck of the iron Bar f is to be moved. The Axis of this is to be placed as exactly as may be, parallel to the Axis of the Earth: at the end or head of the Iron f g, is fitted a Socket h h, with a Screw 4, which

will

will fix it to the head in any posture. This Socket h h in the 15 and 16 Figures, hath a large Joynt to be stiffned by a Screw 5, in which Joynt is moved a strong Bar of Iron, about 4 foot in length, to wit, 2 foot on each side of the Joynt, the one end 6 hath a large weight or counterpoise of Lead 8, which serveth to counter-ballance the whole weight of the Frame and Instrument upon the other, and can be screw'd either nearer to or farther from the Joynt, as there shall be occasion for poising; at the other end of the Iron is a large Ball of Iron 7, to which is fitted also a Socket of Brass 9, with a Screw to fix it and move it, as there shall be occasion. This Socket is fastned under the middle of a Table s s, upon the plain side of which the Quadrant is to lye. Upon some convenient part of this Axis is fixed an Octant or Sextant of a Circle, represented in the 15th. Figure edge-ways, and in the 17th. Figure broad-ways, by 3 3 i i, whose circular edge 3 3 is cut into Teeth, as before is directed; unto these is adjusted a Worm or Screw k, which is the Axis or Arbor of the Wheel l l l; this Wheel is moved round by the weight x, whose Line is coiled round the Barrel u u, and with it it turneth round the Flie n n, by the help of a Screw m, fixed upon the Arbor o o, in the manner of the Flie of a one wheel'd Jack; this Flie moveth circularly the Pendulum p p, in the 15th. and 29th. Figures, which is shortned or lengthned, by slipping up and down the Cylinder q q, the Thread of the Pendulum being fastned at r.

I shall not now spend any more time in the Explication of the making or contriving the circular Pendulum, reserving it for another opportunity and Discourse, wherein I shall shew several useful Contrivances and Inventions about the same, and particularly about this and some other Experiments of motion, which was the cause of the Invention thereof by me long since, in the year 65. Upon which occasion, I cannot but take notice of a Publication, made by *Christianus Hugenius Zulichemius Const. F.* in his Book call'd, *Horologium Oscillatorium sive demotu Pendulorum ad Horologia aptato demonstrationes Geometricæ*; containing a short Description of a circular Pendulum-with somewhat about the Explication of it, without naming, me at all, as concern'd therein, though I invented it, and brought it into use in the year 1665, and in the year 1666, I com-

communicated it to the Royal Society, at their publick Meetings, both as to the Theory and Practick thereof, and did more particularly explain the Isocrone motion of the Ball of a Pendulum, in a parabolical Superficies, and the Geometrical and Mechanical way of making the same move in such a Superficies, by the help of a Paraboloeid, which I caused also to be made and shew'd before the same Society, upon several days of their publick Meeting, where besides many of the Society, were divers strangers of forreign parts. This many of the Royal Society can bear me witness, and the publick Registers thereof do testifie and make appear, and I was told by Sr. *Robert Moray*, that he did then write to Monsieur *Zulichem* concerning the same. But of this more hereafter, when I examine some other things in that Book, about finding the descent of heavy Bodies, and of finding the Longitude of places, and publish some more certain and practicable ways of doing them.

This puts me in mind of publishing an Invention, which I made and produced before the Royal Society, in the same year 1666, much about the same time that I produced the Theory and Experiment of the circular Pendulum compleat, which I call'd the perfection of Wheel-work, as being indeed founded on a principle capable of the greatest perfection can be imagined. It is in short, First, To make a piece of Wheel-work so, that both the Wheel and Pinnion, though of never so small a size, shall have as great a number of Teeth as shall be desired, and yet neither weaken the Work, nor make the Teeth so small, as not to be practicable by any ordinary Workman. Next, That the motion shall be so equally communicated from the Wheel to the Pinnion, that the Work being well made, there can be no inequality of force or motion communicated. Thirdly, That the Point of touching and bearing, shall be always in the Line that joyns the 2 Centers together. Fourthly, That it shall have no manner of rubbing, nor be more difficult to be made then the common way of Wheel-work, save only that Workmen have not been accustomed to make it.

First then, If there be a certain number, and no more of Teeth required to be made in a small Wheel, then must the Wheel and Pinnion consist of several Plates or Wheels, lying one besides the other, in the manner they appear in the 20th. Figure.

Figure. Where ſuppoſe it be required, that the Wheel ſhall have 1000 Teeth, and the Pinnion 100, and yet that the Teeth both of the Wheel and Pinnion have ſufficient ſtrength; take 10 Plates all of equal bigneſs and thickneſs, and by 2 or more Screws fix them firmly together, as if one Wheel, cut this Wheel into 100 Teeth, and compleat it, then fit the middle hole upon the round neck of an Arbor, then unſcrew the Plates, and place them in ſuch order, that the Teeth may gradually follow each other, much after the manner as is expreſt in the 20th. Figure, (though it be there very ill expreſt, by reaſon of the miſtake and failure of the Graver) and with ſuch ſteps, that the laſt Tooth of one Degree, may within one ſtep anſwer to the firſt Tooth of the next Degree. I call the 10 Teeth comprehended within the lighter part, a b c d, or e f g h, or i k l m, a Degree of Teeth in ſteps, and d c f e, or h g k i, are Degrees of Notches between the Teeth, and the Tooth b c, which is the laſt towards the right hand, ſhould have been placed within one ſtep as low as e h, the firſt of the next Degree on the left ſide, (though it be much otherwiſe here graven) whence all the inequality in the touching, bearing or rubbing, in a Wheel-work thus well made, would be no more then what could be between the 2 next Teeth in one of the Degrees, which would be much leſs then a 10th. part, of what muſt neceſſarily happen in a Wheel of one Plate of 100 Teeth only.

Secondly, If it be deſired, that the Wheel and Pinnion ſhould have infinite Teeth, all the ends of the Teeth in the Degrees of the 20th. Figure, muſt by a Diagonal ſlope be filed off, and reduced to a ſtraight, as in the 21, which may indeed be beſt made by one Plate of a convenient thickneſs, which thickneſs muſt be more or leſs according to the bigneſs of the ſloped Tooth. And this is to be always obſerved in the cutting thereof, (though it be otherwiſe and very falſly expreſt in the 21 Figure) that the end of one ſlope Tooth on the one ſide, be full as forward as the beginning of the next Tooth on the other, that is, that the end b c of one Tooth on the right ſide, be full as low as e h, the beginning of the next Tooth on the left ſide, (though by the Gravers miſtake it be here quite otherwiſe expreſt.) I ſhall not ſpend more time in explicating the Pinnions, r s t u, r s t u, of the 20 and 21 Figures, which are to anſwer

ſwer the Teeth of the Wheels, they being plain enough to any perſon a little verſed in Mechanicks, and becauſe the further and more full Explication of the form and reaſon of this and other Wheel-work, is compriſed in another Diſcourſe, which I may afterwards publiſh.

But to proceed where I left at this Digreſſion, to the finiſhing of the Deſcription of the Inſtrument for moving the Quadrant, ſo as alway to reſpect the Object. The conical hole, in which the end of the Axis is to move, may be made after the form expreſſed in the 18th. Figure, where a a a a repreſents an iron Frame ſcrew'd faſt to the Floor, b b b b the iron piece, containing the conical ſteel hole, c c c c 4 long Screws, by which the piece is moved and fixed in any part of the ſpace, included within the Frame a a a a; this by a ſtrong ſpringing Frame underneath, is kept down cloſe to the Superficies of the Floor, and cannot in any wiſe totter or ſhake. There is no great difficulty in the Contrivance, and therefore I ſhall proceed.

In the next place then, having ſhew'd the way how to keep the Inſtrument, in the Plain of two Objects that are to be obſerv'd, I ſhall ſhew, by what means a Quadrant may be kept always Perpendicular, and in the Azimuth of the celeſtial Object. And this I do, by a ſmall addition to the former Contrivance; that is, Let a b in the 22 Figure, repreſent the Axis deſcribed in the former Contrivance, accommodated with all the Contrivances of the moveable Center below, of the Clock-work of the circular Pendulum, to keep it moving equally round in the middle, and of the Collar e above. But unto the ſmall Neck f muſt be joyn'd a ſemi-circular piece of Iron c d, with a Center-hole in each arm at c and d, to receive the Pevots i i, of the circular piece of Iron x, in the 22 and 23 Figures; upon the ſecond Floor o o, muſt be ſtedfaſtly fixed a Bow or Frame of Iron h h, which muſt have a hole through it, exactly over the middle of the Plate x, this is to be a Collar for the Neck k, of a perpendicular Axis l k, which by means of a moveable Center fixed in the cieling, in which the Point l moves, may be exactly adjuſted to a Perpendicularity; to this Axis at right Angles is fixed a Frame m m, ſteadied by the Brakets or Braces n n; upon this Frame

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the fixed Sights of the Quadrant, are laid and adjusted to an exact Horizontality, and the Plain of the Quadrant being once adjusted to the Plain of the celestial Object, will by the circular Pendulum moving the Axis a b, in an equal motion with that of the Object about the Axis of the Earth, be always kept in the Plain of the Object, whose Azimuth and Altitude is to be observed. Now the motion of the under or inclining Axis a b, is communicated to the perpendicular Axis l k, by means of the circular Plate x, in the 22 and 23 Figures, for the semi-circular Arms c d of the lower Axis, taking hold of the Points 1 1 of the Plate x, and the semi-circular Arms of the upper Axis, taking hold of the Points 2 2 of the said Plate, the perpendicular Axis is moved in a proportionate motion with the inclining Axis a b, which Proportion is Geometrically and strictly such as it ought to be, to keep the Plain of the Quadrant exactly in the Azimuth of the celestial Object, as any one never so little versed in Geometry, will easily find; and I shall hereafter more at large demonstrate, when I come to shew, what use I have made of this Joynt, for a universal Instrument for Dialling, for equalling of Time, for making the Hand of a Clock move in the Shadow of a Style, and for performing a multitude of other Mechanical Operations.

The next thing I have to explain, is the way of finding how many Revolutions of the Screw, and what parts of a Revolution go to make a right Angle, or 90 Degrees upon the Quadrant. For the doing of which, I must, in a place where I can have a good Prospect for a semi-Circle, first direct both the Sights of the Telescopes directly at the same Object, and the same Point thereof, and then rectifie the Indices to 0, or the beginning of the Divisions; then I turn the Screw, till as near as I can measure with Compasses, the moveable Telescope hath moved a Quadrant, and through the three Telescopes take notice of three Points in the Horizon, that is to say, two Points exactly opposite one to another, in respect of the Center of the Quadrant, and a third pretty near the middle between them, in the same respect, which I further adjust thus; I shew'd before how I rectifi'd the fixed Sights, so as to look exactly forwards and backwards, which being accordingly done, I observe the supposed right Angle, with the moveable Sight on the Quadrant,

and with the Sight fixt on the Quadrant looking forwards, and note diligently the two Objects pointed at; then without moving the Screw, or moveable Arm upon the Quadrant, I find those Objects through the moveable Sight, and the fixt Sight, looking backwards, and directing one of the Sights exactly to one Point, I observe, how much the other doth vary from the other Object, either by being within it or without it; then half that Difference, as near as I can judge by my Sight, and move the moveable Sight by the help of the Screw, so as to respect the middle Point: Then I observe this second found Angle, by the fixt Sight looking forwards, and by the moveable Sight, and see whether there be any Difference, and if I find any, as near as possible, I adjust it again, to half this last Difference, and so continue to examine and adjust, till I am certain, that the Angles on each side of the moveable Tube, between the same and the Sights, looking forwards and backwards, are equal to each other, and consequently are both right Angles, or Quadrants of a Circle. Which when I have found, I observe, by the Indices on the Screw-Plate and Limb, how many Revolutions, and what part of a Revolution, the Screw hath been turned to open that Angle; this Number I set, as the Number answering to 90 Degrees, and dividing that Number into 90 equal parts, I have the Numbers that belong to every Degree, and dividing the common Difference between them into 60 parts, I find the Numbers answering to the Minutes of the Quadrant, and dividing the common Difference between the Minutes into 60 parts, I easily make the Numbers answering to the Seconds; but these will be needless, for subducting the next Number, less then it in the Table from the Number observed, you have the Degree and Minute, and some Number perhaps over, which may presently be found by one small Table of the common Differences of Seconds. See page 55.

Here methinks I hear some object possibly, That the Divisions on the Quadrant, do not exactly correspond to the Divisions made on the Plate. I answer, That in part they do, and in part they do not. First, They concur, in that all the Divisions made by whole Revolutions, shew exactly the same by the Indices, that they do upon the Quadrant. Secondly, I say, in part they do not, that is, the parts of any single Revolution,

lution, are not exactly and Mathematically the same pointed out by the Index, upon a Ring equally divided, that are made upon the Limb of the Quadrant. But yet, I say, they are sensibly equal even to the sense, assisted by a 60 foot Telescope, and consequently need no manner of rectification; but yet if any one will be so curious and nice, he may make the Divisions on the Index-Ring, according to the proportion of the Differences of the Tangents, that are subtended within half the compass of the distance of the two next Threads. As suppose in the above-mention'd instance, half the Distance of two Threads be the Tangent of three Minutes, or thereabout; if we examine any large Table of Natural Tangents, we shall find the Differences between the Minutes themselves, even till six Minutes, (which is much more then double three) doth not differ above one or two parts of a thousand thousand, which is 1000 times more nice, then our Sight, even with Glasses, can arrive to, much less then will be the difference between the Differences of the Seconds; and therefore it will be a niceness meerly notional, and of no use, and as such, ought to be omitted, and the plain and equal Divisions made use of, they being as to all sense true and perfect, and proper Divisions, though as to curiosity of Theory and Calculation, unequal.

Now I have done, possibly some may say, To what purpose all this curiosity? To which I answer, That though possibly in many common cases 'tis of but little value, yet I conceive in general, that it is of infinite value, to any that shall design to improve Geography, Astronomy, Navigation, Philosophy, Physicks, *&c.* And to instance in some particulars, I conceive,

First, That one use of this Instrument, may be for taking the exact Refraction of the Air, from the Horizon to the Zenith; by which we shall be able not only to rectifie all Observations, and clear them from Refractions, which in some Observations, especially those of Parallax, is absolutely necessary, but it may give us a new means to judge of the qualities and constitutions of the Air, as to the seasons of the year, and the temperature of the weather, which are to succeed. For 'tis most certain, that there is as great a variety in the re-

fractiveneſs of the Air, as there is in the heat and cold, gravity and levity, dryneſs and moiſture, rarefaction and condenſation thereof, and ſometimes when none of thoſe do ſeem at all to be ſenſibly alter'd, its refractiveneſs hath been very much varied, which change does ſeem to proceed from ſome alterations in the upper Regions thereof, far removed from the Superficies of the Earth, and is ſometimes many days in deſcending and fermenting, as it were deeper and deeper, into the lower Regions of the Air, before it deſcend ſo low as the bottom thereof next the Earth. But of this much more in another place.

A ſecond uſe is for regulating the places of the fixt Stars, as to their Longitudes and Latitudes, and Diſtances from one another, eſpecially thoſe within the Zodiack, by which we ſhall in a ſhort time be able to judge, whether thoſe Bodies that we account ſo fixt and conſtant, do not vary their Poſitions one to another, which I have very good grounds to believe they do.

A third uſe of this Inſtrument, is for regulating the places of the Planets, by their Appulſes to thoſe fixt Stars, ſo that not only Aſtronomy will be perfected, but the Longitude of places upon the Earth, (a thing ſo highly advantageous for Trade and Navigation) will of conſequence follow, which without ſuch an Inſtrument as this, is in vain expected from the Heavens.

A fourth uſe of this may be for ſtating the exact Latitude of places to a Second, whereby we ſhall quickly know, whether thoſe Latitudes do vary, as well as the variation of the Loadſtone, which hath been conjectur'd, not without ſomewhat of probability, but is hardly to be determined, without ſome ſuch accurate way of Tryal, as this Inſtrument is capable of performing.

A fifth uſe of it may be, for examining what influence the approach or receſs of the other Planets have upon the Earth, as to its Periodical motion, and what influence the Earth hath upon them as to theirs; for I have good ground to believe, each of theſe to have influence upon one another, and to cauſe ſuch motions, as have hitherto much confounded all Aſtronomical Hypotheſes and Calculations: Of which I ſhall ſay more on another occaſion.

A sixth use may be for measuring the quantity of a Degree upon the Earth; the best Experiment of that kind, that is yet publick to the World, is that of Mr. *Norwood*, made between *London* and *York*: But if we examine with what Instruments he made it, we shall find, that he was not certain in either of his Latitudes to a Minute, and consequently could not be certain of the quantity of the Earth, answering to his supposed mark to two miles, and consequently it could not be made the common standard of all measure. But by the means of this Quadrant, all Latitudes may be certainly taken to a Second, and consequently the error in 150 miles, cannot be more then the 30th. part of a mile, and consequently a foot, or yard, or rod, this way stated, cannot vary above a 6000 part of its length, which is sufficiently accurate for a universal and common standard of all measure and quantity, to which all other measures in the World should be referr'd and proportioned. This was the occasion of the contriving and making thereof; His Sacred Majesty having commanded me to see that Experiment accurately performed, and to give Him a true Account thereof, which had been before this performed, had not my indisposition of health prevented.

A seventh use may be for measuring the Distance between two places, exactly in a straight Line. This it will perform to admiration, by the exactness of taking the Angles, if some length be exactly measured at the place that is to be the Object, insomuch that 'tis hardly possible, by any other means in the World, to come to that exactness, nay, though there were a continued Plain extended between the two places, whose Distances are to be found, and the same were carefully measured with Chains, Rods, or Wheels. By this means the Distance of a Ship on the Sea, can be found more exactly, then any other way whatsoever, by one or two Stations, and a multitude of Philosophical Tryals under this Head, which are not practicably to be done with any tolerable accurateness, by other ways.

An eight use may be for taking the exact Diameters of the Sun, Moon, and Planets, even to a Second, and the Distance of the smaller appearing Planets from the fixt Stars, near adjoyning. Now because for this Design, it may perhaps seem a little too

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fractiveneſs of the Air, as there is in the heat and cold, gravity and levity, dryneſs and moiſture, rarefaction and condenſation thereof, and ſometimes when none of thoſe do ſeem at all to be ſenſibly alter'd, its refractiveneſs hath been very much varied, which change does ſeem to proceed from ſome alterations in the upper Regions thereof, far removed from the Superficies of the Earth, and is ſometimes many days in deſcending and fermenting, as it were deeper and deeper, into the lower Regions of the Air, before it deſcend ſo low as the bottom thereof next the Earth. But of this much more in another place.

A ſecond uſe is for regulating the places of the fixt Stars, as to their Longitudes and Latitudes, and Diſtances from one another, eſpecially thoſe within the Zodiack, by which we ſhall in a ſhort time be able to judge, whether thoſe Bodies that we account ſo fixt and conſtant, do not vary their Poſitions one to another, which I have very good grounds to believe they do.

A third uſe of this Inſtrument, is for regulating the places of the Planets, by their Appulſes to thoſe fixt Stars, ſo that not only Aſtronomy will be perfected, but the Longitude of places upon the Earth, (a thing ſo highly advantageous for Trade and Navigation) will of conſequence follow, which without ſuch an Inſtrument as this, is in vain expected from the Heavens.

A fourth uſe of this may be for ſtating the exact Latitude of places to a Second, whereby we ſhall quickly know, whether thoſe Latitudes do vary, as well as the variation of the Loadſtone, which hath been conjectur'd, not without ſomewhat of probability, but is hardly to be determined, without ſome ſuch accurate way of Tryal, as this Inſtrument is capable of performing.

A fifth uſe of it may be, for examining what influence the approach or receſs of the other Planets have upon the Earth, as to its Periodical motion, and what influence the Earth hath upon them as to theirs; for I have good ground to believe, each of theſe to have influence upon one another, and to cauſe ſuch motions, as have hitherto much confounded all Aſtronomical Hypotheſes and Calculations: Of which I ſhall ſay more on another occaſion.

A ſixth uſe may be for meaſuring the quantity of a Degree upon the Earth; the beſt Experiment of that kind, that is yet publick to the World, is that of Mr. *Norwood*, made between *London* and *York*: But if we examine with what Inſtruments he made it, we ſhall find, that he was not certain in either of his Latitudes to a Minute, and conſequently could not be certain of the quantity of the Earth, anſwering to his ſuppoſed mark to two miles, and conſequently it could not be made the common ſtandard of all meaſure. But by the means of this Quadrant, all Latitudes may be certainly taken to a Second, and conſequently the error in 150 miles, cannot be more then the 30th. part of a mile, and conſequently a foot, or yard, or rod, this way ſtated, cannot vary above a 6000 part of its length, which is ſufficiently accurate for a univerſal and common ſtandard of all meaſure and quantity, to which all other meaſures in the World ſhould be referr'd and proportioned. This was the occaſion of the contriving and making thereof; His Sacred Majeſty having commanded me to ſee that Experiment accurately performed, and to give Him a true Account thereof, which had been before this performed, had not my indiſpoſition of health prevented.

A ſeventh uſe may be for meaſuring the Diſtance between two places, exactly in a ſtraight Line. This it will perform to admiration, by the exactneſs of taking the Angles, if ſome length be exactly meaſured at the place that is to be the Object, inſomuch that 'tis hardly poſſible, by any other means in the World, to come to that exactneſs, nay, though there were a continued Plain extended between the two places, whoſe Diſtances are to be found, and the ſame were carefully meaſured with Chains, Rods, or Wheels. By this means the Diſtance of a Ship on the Sea, can be found more exactly, then any other way whatſoever, by one or two Stations, and a multitude of Philoſophical Tryals under this Head, which are not practicably to be done with any tolerable accurateneſs, by other ways.

An eight uſe may be for taking the exact Diameters of the Sun, Moon, and Planets, even to a Second, and the Diſtance of the ſmaller appearing Planets from the fixt Stars, near adjoyning. Now becauſe for this Deſign, it may perhaps ſeem a little too

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cumberſom, and by reaſon of its ſhort Tubes, ſomewhat too ſmall, I have therefore contrived an Inſtrument of 6 times the length or radius, which will take in an Angle of about 5 Degrees, and yet take in the whole Angle by one glance of the eye, and determine the meaſure thereof to leſs then a Second. I have likewiſe invented and made a new Helioſcope, by which the Body of the Sun may be look'd on as inoffenſively to the eye, as a ſheet of white Paper; of great uſe for ſuch, as will make Phyſical Obſervations of that glorious Body. Theſe I will in ſome enſuing Papers deſcribe.

A ninth may be for exactly taking the Level, for the conveyance of a River or Water from place to place; and under that Head of performing infinite of Philoſophical Experiments, which can hardly be try'd by any other way in the World, about the Refractiveneſs of the Air near the Earth, whereby diſtant places ſometimes appear, and ſometimes diſappear, under the Horizon. By this means alſo the Rotundity of the Earth may be truely found, vaſtly ſurpaſſing any thing performed by the beſt Levels yet known. To this we may add, the height of Hils, if their diſtance be known, or their diſtance, if their height be known.

I could have enlarged upon theſe, and have named divers others; but deſigning it only as an Anſwer to ſuch, as may captiouſly put ſuch a Queſtion, I ſhall rather leave the pleaſure of finding them, to ſuch as ſhall really ſeek them, to be aſſiſted thereby in their own undertakings.

FINIS.

Errata.

PAg. 2. l. 13. r. $\frac{2}{10}$ p. 6. l. 14. r. *aquilæ*. p. 13. l. 3. r. *Mathematician*. p. 15. l. 11. r. *Fig.* 32. p. 13. l. 28. r. *Fig.* 31. p. 18. l. 39. r. *ſtructuram*. p. 21. l. 26. r. *dena minuta*. p. 21. l. 27. r. *diſcriminatim*. p. 22. l. 3. r. *Fig.* 35. p. 28. l. 34. r. *quædam*. p. 32. l. 21. r. *ſhaking*. p. 33. l. 8. r. *focus*. p. 39. l. 28. r. *res*. p. 40. l. 11. r. *admoveant*. p. 40. l. 39. dele *ſe*.